THE WEATHER AND CIRCULATION OF DECEMBER 1956[1]

A MONTH WITH LARGE WEEKLY FLUCTUATIONS

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1. ZONAL INDEX AND GENERAL CIRCULATION

December's mean circulation in the Northern Hemisphere was quite asymmetrical about the North Pole, as shown by the fields of mean 700-mb. height and its departure from normal (fig. 1). The large positive anomaly over northern Siberia, for instance, contrasted with negative values at similar latitudes in the Western Hemisphere. It is not unusual for adjacent regional circulations to be different in form, in the sense that one may exhibit high-index characteristics while low index is observed in the other [1, 2, 3]. Such was the case in December 1956. It is perhaps more unusual for the entire Western Hemisphere to fit into the high-index category as well as it did this month.

While no quantitative measure of circulation indices is routinely available for the Eastern Hemisphere, the departure from normal (DN) pattern in figure 1 leaves little doubt that a low zonal index and high-latitude blocking were dominant features of the circulation in that region. The positive anomaly center (+550 ft.) over northern Siberia was the largest 700-mb. height departure from normal in the Northern Hemisphere. An extension of the surrounding positive DN field eastward to the Bering Sea was accompanied by a large area of negative anomaly in the west-central Pacific.

Eastward from the central Pacific, however, the pattern exhibited a number of features typically associated with high index, among them an unusually deep Icelandic Low and abnormally strong subtropical ridges in the eastern Pacific and western Atlantic Oceans. Some westerly component of mean 700-mb. DN flow was observed over the entire extensive area bounded by 40° and 60° N. lat., and 140° W. long. eastward to central Europe.

An index cycle of some 5 weeks' duration was terminated with December's high values shown in figure 2. The cycle was remarkable because of its amplitude, with a range of more than 9 meters per second in 5-day mean values, from a low of 6.5 m. p. s. in late November to a high of 16 m. p. s. in December. Namias [1] indicated that November might be a favorable time for index cycles, although the principal cycle usually occurs in February or March. The marked variations of the Western Hemisphere zonal index this month will be discussed in subsequent paragraphs on intramonthly variability.

[1] See Charts I–XVII following p. 458 for analyzed climatological data for the month.

TABLE 1.—*Stations reporting highest average December temperature (°F.) of past 50 years in December 1956. All are new records except those marked* *

Station	Mean temperature	Positive departure from normal
Macon, Ga	56.3	6.6
Baltimore, Md	46.5	7.7
Atlantic City, N. J	45.2	7.0
Asheville, N. C	49.3	9.1
Charlotte, N. C	53.1	10.1
Winston-Salem, N. C	49.8	9.2
Columbia, S. C	56.2*	9.2
Florence, S. C	56.3	9.8
Chattanooga, Tenn	51.4	9.3
Knoxville, Tenn	51.4*	10.4
Nashville, Tenn	50.3*	8.7
Lynchburg, Va	47.7*	8.8
Norfolk, Va	52.2	9.4
Richmond, Va	48.9	9.4
Charleston, W. Va	46.9	8.8
Elkins, W. Va	42.1	9.2

*Higher temperatures were observed in December 1889.

The geographical distribution of wind speeds at 700 mb. accompanying Siberian blocking and downstream high-index is well illustrated in figure 3. In the Pacific the mean 700-mb. jet stream was depressed southward from both the November 1956 (dashed) and the December normal (not shown) positions. Downstream however, the westerlies were close to their normal December location, but unusually strong, as shown by wind speeds in excess of normal (fig. 3B) along the entire route of the mean 700-mb. jet stream.

2. ZONAL INDEX AND UNITED STATES WEATHER

United States temperatures reacted to the increased zonal index in striking fashion by warming extensively (with respect to normal) over the preceding month. Of 100 representative stations, 79 were warmer than in November by one or more temperature anomaly classes (out of 5) and only 6 were colder by at least one class. One or more stations in 8 States reported record high average temperatures for December (see table 1), while new record daily highs were established in 27 States.

Much above normal temperatures in the East (see Chart I-B) were closely related to the unusual strength of the Bermuda High. Figure 1 shows positive values of 700-mb. height anomaly over this area, together with a

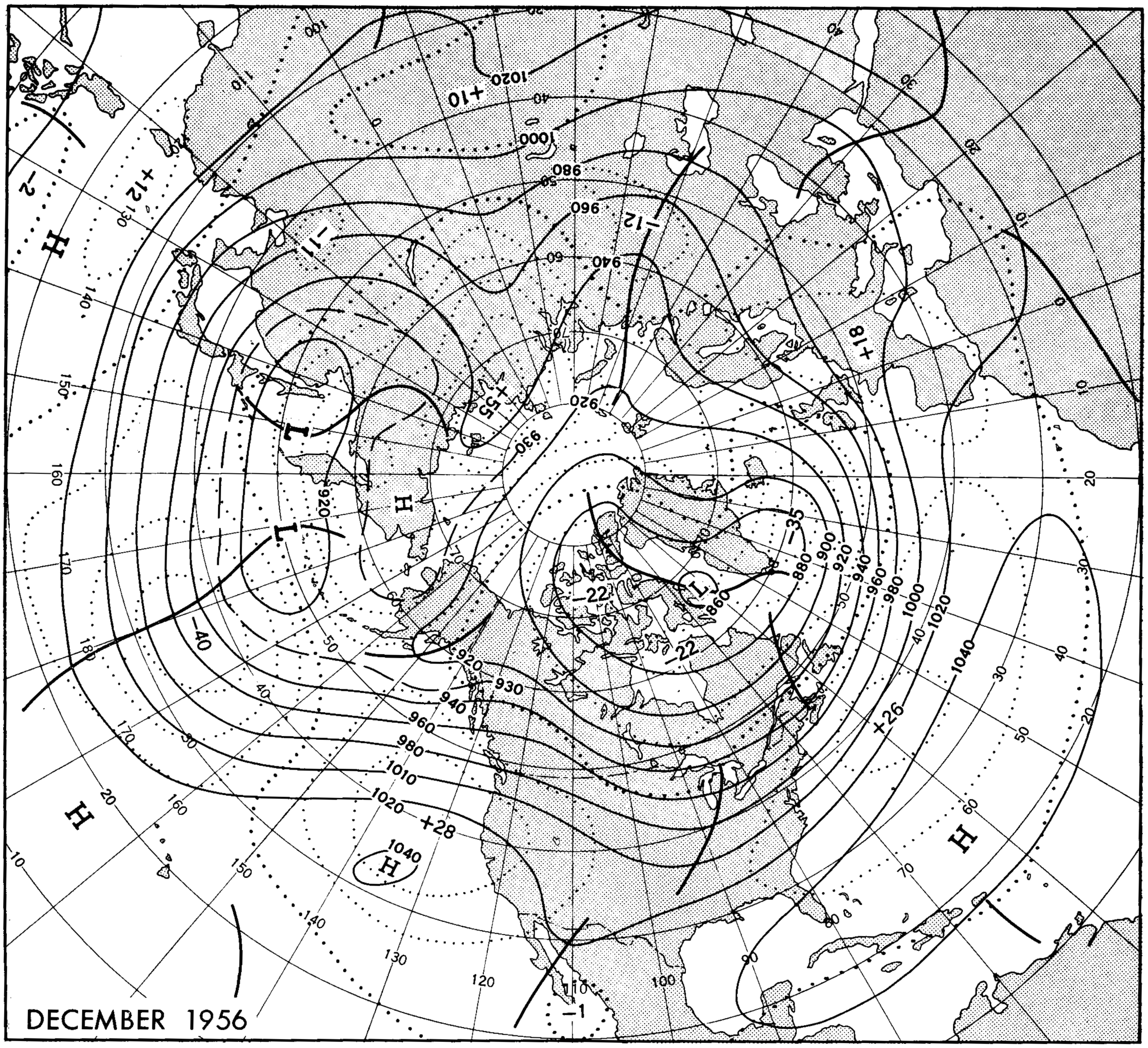

Figure 1.—Mean 700-mb. contours and height departures from normal (both in tens of feet) for December 1956. The contrast between Eastern and Western Hemisphere circulation characteristics is readily apparent in the departure from normal pattern.

southerly component of 700-mb. DN flow. Less directly related was the northward displacement (from normal) of preferred paths of daily systems (Charts IX and X). The principal anticyclone path in figure 4B, for instance, illustrates the tendency for cold polar continental Highs to "glance" eastward this month, instead of penetrating the subtropical ridge in the Southeast. According to Klein [4], an anticyclone track of this sort, passing just north of the Great Lakes, is quite common in winter when the westerlies are strong.

The weather in the eastern half of the United States was not predominantly dry as customary with high zonal index values, probably because of the abundant moisture supplied by southerly DN flow from the Gulf. Figure 4A, showing the paths of maximum cyclone frequency, helps explain the rather complicated distribution of precipitation in the eastern United States, where three separate bands of above normal amounts were located (Chart III-B). Heavy precipitation near the north central border and from Missouri to New England was attributable to cyclone activity. The southernmost zone, from eastern Texas to the southern Appalachians, probably resulted from lifting, partly orographic and partly frontal in nature.

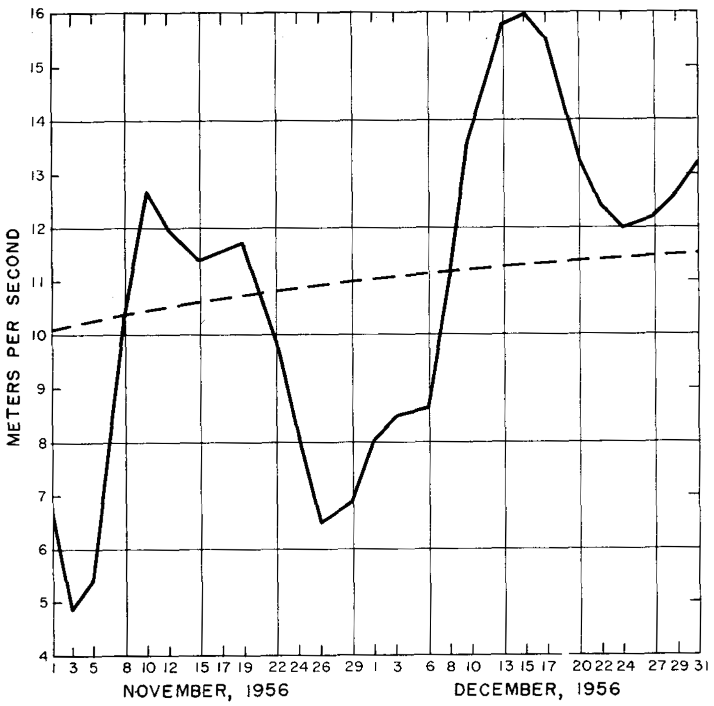

FIGURE 2.—Time variation of the temperate-latitude zonal index (average strength in meters per second of the 700-mb. zonal westerlies between 35° N. and 55° N. and from 5° W. westward to 175° E.) for November through December 1956. The solid line connects 5-day mean zonal index values (plotted at the middle of the period). Dashed line indicates normal index values.

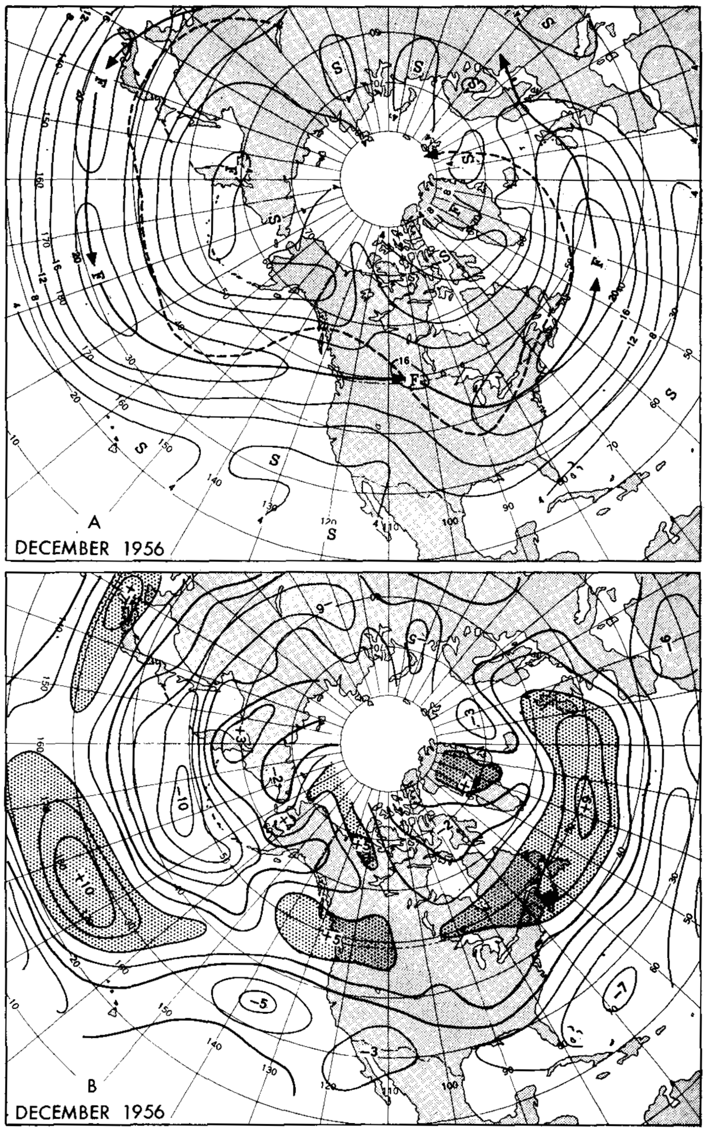

FIGURE 3.—(A) Mean 700-mb. isotachs and (B) departure from normal wind speed (both in meters per second) for December 1956. Solid arrows in (A) indicate position of the primary jet axis at the 700-mb. level in December and dashed arrows the position for November. "F" and "S" designate wind speed maxima and minima.

More in line with the usual high-index pattern were the large amounts of precipitation in the Northwest and lesser amounts downstream, where the moisture had been removed by orography. In the Southwest, where any northeasterly component of DN flow lessens the likelihood of precipitation, amounts were very small. Dry hot winds over southern California's forest regions the last three weeks of December renewed the serious threat of fire so prevalent in November.

After the temporary drought relief in October described by Hawkins [5] many critical areas finished the year with little additional precipitation. This was particularly true of western Oklahoma and Texas, and central Kansas. The year ended as a record dry one over portions of Iowa, Kansas, Oklahoma, Texas, New Mexico, Arizona, and Florida. The greatest deficits in Florida occurred in coastal areas of the southern half of the State.

3. INTRAMONTHLY VARIABILITY

Dunn, in the previous article of this series [6], described the pronounced intramonthly fluctuation of circulation and weather patterns in November and pointed out indications of some stability of circulation in the last two weeks. The persistence was short-lived, however, and subsequent changes seemed large enough to justify continuation into December of the analysis by weekly periods. Five-day mean 700-mb. charts in figure 5 and wind profiles in figure 6 were selected to represent circulations associated with the 7-day periods of temperature anomaly shown in figure 7 and the precipitation totals in figure 8.

Some idea of the magnitude of Western Hemisphere circulation changes during the month is shown in figure 2, where 5-day mean values of the zonal index are represented by the solid curve. The similarity between the index behavior in November and December is shown by this curve, in that the highest values occurred toward the middle of each month with much lower values at either end. The overall average was much higher, however, in December than in November. Another feature common to both months was a reversal in United States circulation. Both months began with a mean trough in the West and a mean ridge in the East, and ended with

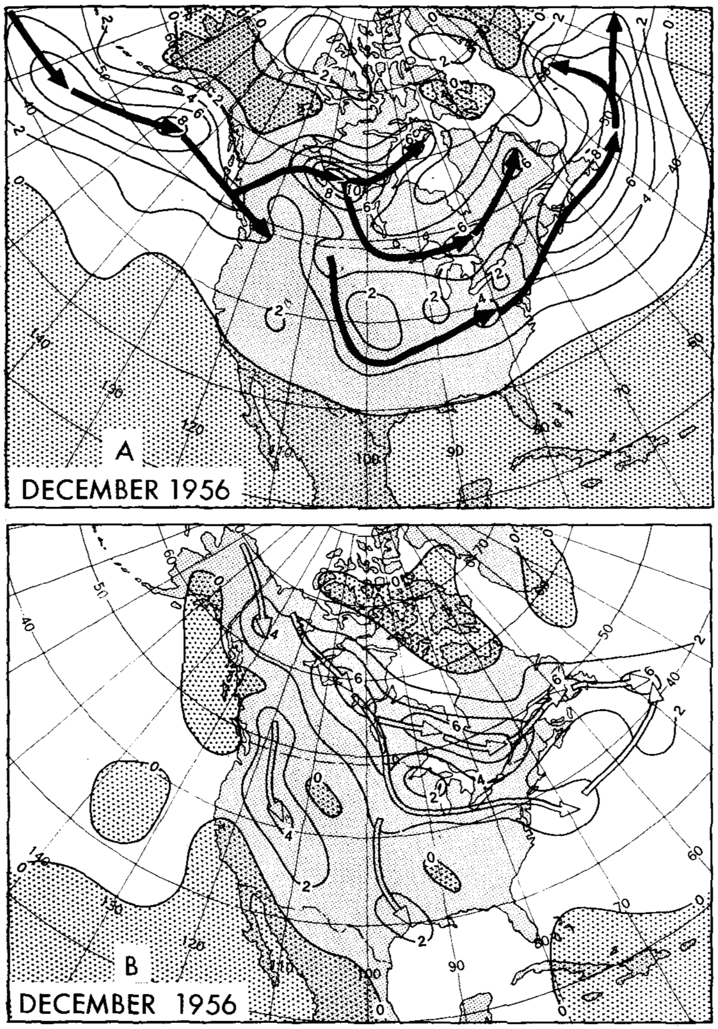

FIGURE 4.—Frequency of cyclone passages (A) and anticyclone passages (B) (within 5° squares at 45° N.) during December 1956. Well-defined cyclone tracks are indicated by solid arrows and anticyclone tracks by open arrows.

the opposite pattern. The 700-mb. maps of the final week in each month were remarkably alike.

DECEMBER 3–9

The 5-day mean 700-mb. height and departure from normal chart for December 4–8 (fig. 5A) displays a strong blocking anticyclone over the Bering Sea. This center is believed to have been largely the result of discontinuous retrogression, in a week's time, of a mean ridge from western North America. To its south a mean trough, associated with negative 700-mb. height anomalies of more than 600 feet, remained nearly stationary.

During the same week the 5-day mean ridge over the western United States was replaced by a mean trough. A similar reversal took place in the eastern United States, where a 380-foot negative DN center was replaced by the 370-foot positive center shown in figure 5A. In the Atlantic the pattern flattened considerably and the westerlies increased at mid-latitudes, as the zonal index continued to rise from the strongly below normal values of late November (fig. 2). The 5-day mean wind speed profile in figure 6A clearly outlines the latitudinal extent of the wind speed deficit with respect to normal during this week.

Over the United States there appeared an apparent deviation from the usual relationship between surface temperature anomaly and 700-mb. DN flow [7]. While the DN flow reversed completely from north-northeasterly to south-southwesterly over the central United States, surface temperatures fell sharply (fig. 7a). This was due to the intrusion of an extremely cold but shallow mass of Arctic air into the United States from Canada. The propelling force for this cold air outbreak is shown by strong northerly DN flow over Alaska and western Canada in figure 5A. Since the shallow cake of air was shielded from opposing upper-level flow by the Rocky Mountain barrier, its momentum was sufficient to allow strong southward penetration into central United States.

The front at the leading edge of the cold air mass became nearly stationary in the eastern United States and the Southern Plains in a zone delineated rather well by the southern boundary of heavier precipitation observed for the week (fig. 8a). The adjoining article by Smith and Wilhelm [8] describes the precipitation associated with this cold front, as warm Gulf air overran the cold polar air. Lesser amounts accompanied the cold front as it moved slowly, but with limited moisture, over and west of the Continental Divide. The mean trough and orographic features along the West Coast contributed to significant precipitation totals from central California northward.

DECEMBER 10–16

Much of the positive anomaly center associated with the Bering Sea blocking anticyclone of early December had retrograded to northern Siberia by mid-month. During the same period a mean trough near the eastern Asiatic coast weakened at all but low latitudes. Thus the Pacific was left with but one mid-latitude mean trough, represented in the DN pattern by a large area of below normal anomaly in the west central Pacific (fig. 5B). This latter mean trough had retrograded to a position favoring the wavelength adjustment which was partly responsible for rising zonal index downstream.

The 5-day mean zonal index for the Western Hemisphere this week reached 16 meters per second, the highest observed for any 5-day mean period of the 14 Decembers of record. Factors associated with this high index value included strong development of the eastern Pacific and Bermuda Highs [1, 9] and a vigorously deepened Icelandic Low.

Figure 2 illustrates the rapidity of the index changes, and figure 6, the latitude band most affected by the changes. For instance, in figure 6B the 5-day mean wind speed between 45° N. and 50° N. increased over 10 m. p. s. from the December 4–8 value.

Rising heights and increasing westerlies at the 700-mb.

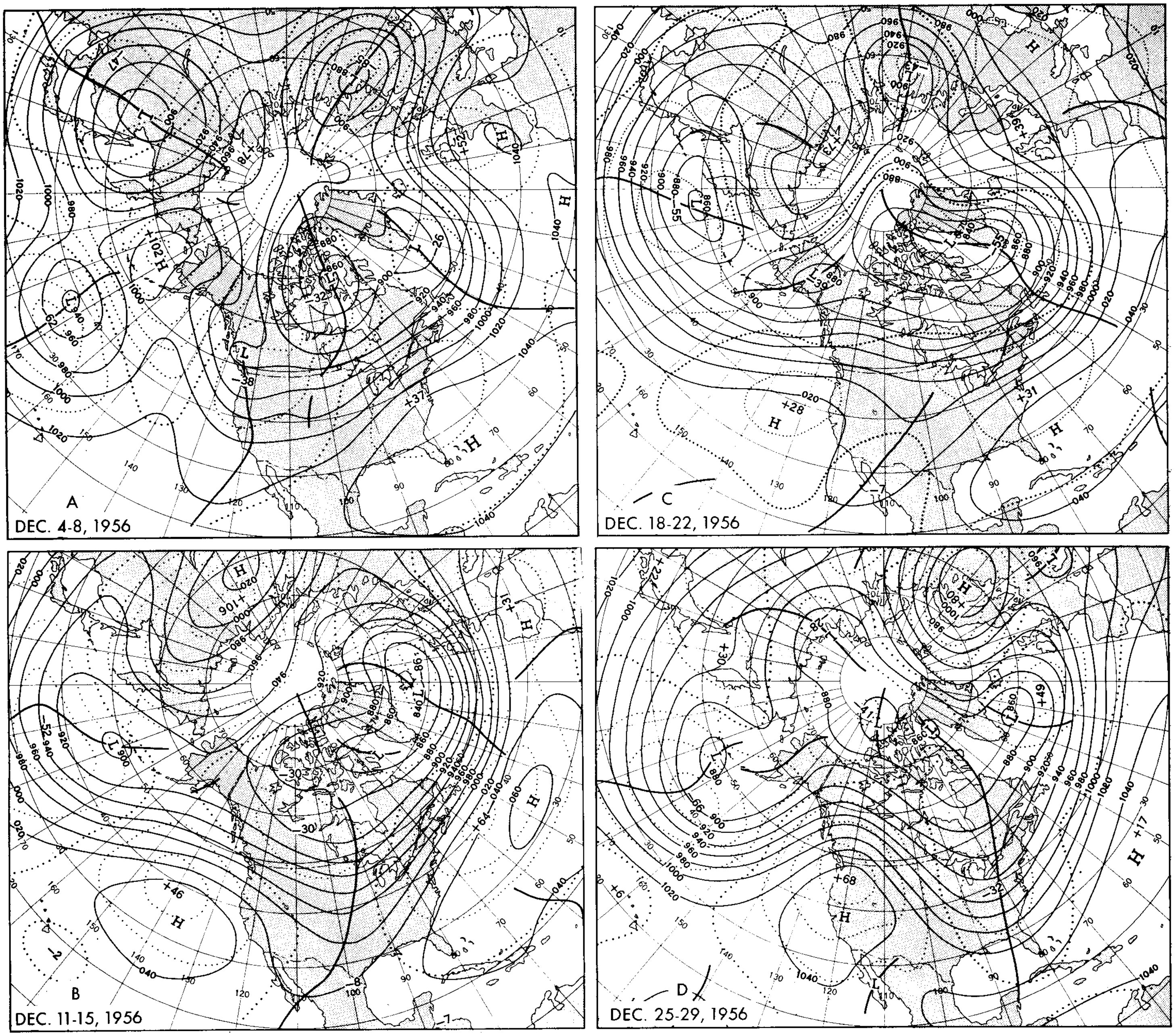

FIGURE 5.—Five-day mean 700-mb. contours and height departures from normal (both in tens of feet) for selected periods in December 1956 one week apart. Lack of persistence from week to week was an outstanding aspect of circulation in December.

level over western United States caused rapid warming over this area, except in Arizona and New Mexico where northerly DN flow prevailed. Foehn warming just east of the Continental Divide was extensive from Montana to the Texas Panhandle, but some cooling accompanied a new wedge of Canadian air in a broad zone roughly 700 miles wide from eastern Texas to southern Lake Michigan (see fig. 7b). While this outbreak of Continental Polar air was weaker than its predecessor, associated frontal precipitation amounts were enhanced by an approaching mean trough (fig. 5B), and large totals were accumulated from Louisiana to the southern Appalachians. Damaging storms of freezing rain and snow in the Northeast, and heavy frontal and orographic rains in the Northwest highlighted the week's precipitation pattern.

DECEMBER 17–23

Changes this week were much less pronounced in the Western Hemisphere than in the previous week, with small displacement and weakening centers of action the general rule. Notable exceptions were cyclonic development in the Gulf of Alaska and rising heights in the North European-Icelandic area (fig. 5C). Zonal westerlies (figs. 2 and 6) diminished as the Icelandic Low filled and the western Atlantic mean ridge weakened and retrograded. Positive values of 700-mb. height anomaly

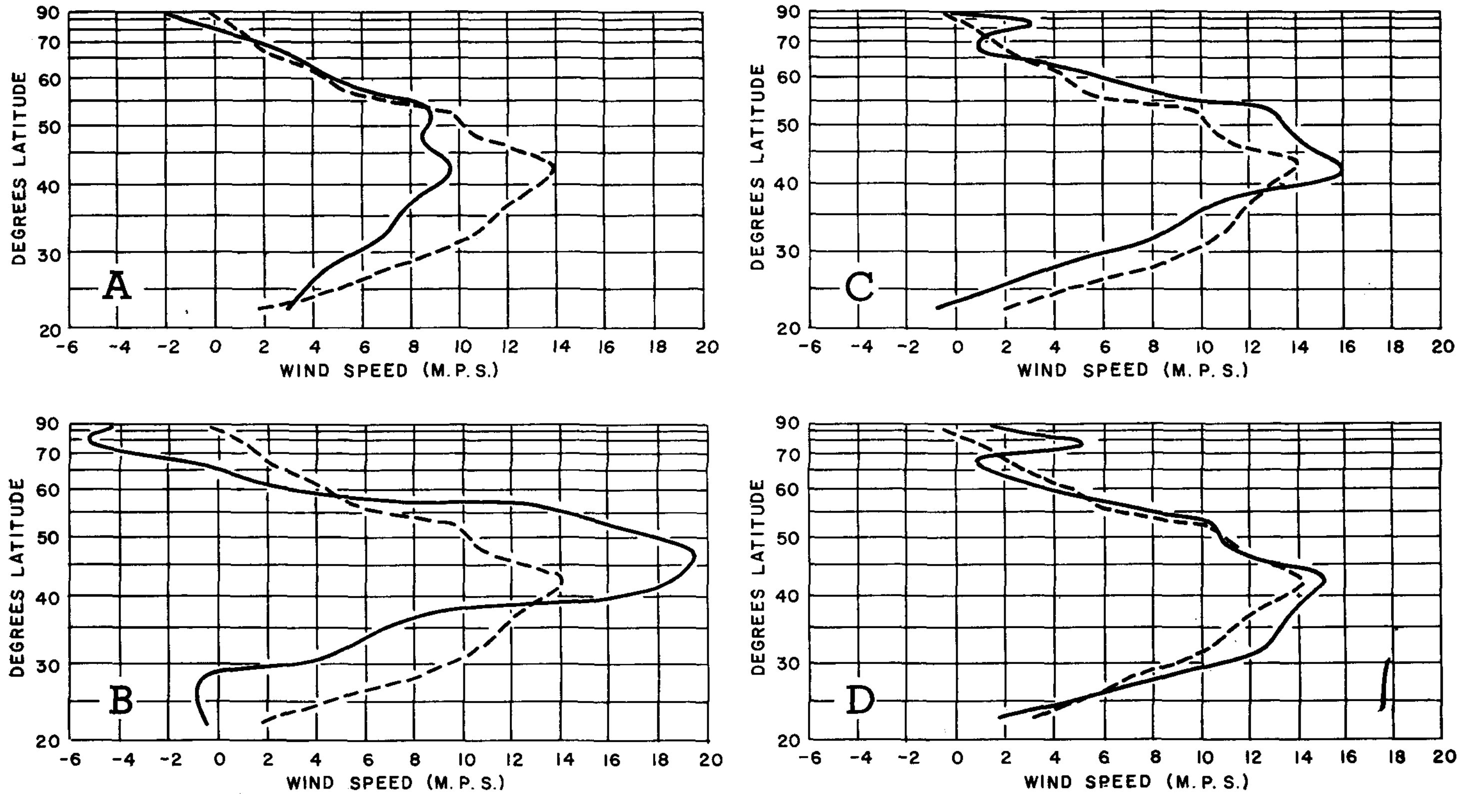

FIGURE 6.—Five-day mean zonal wind speed profiles in the Western Hemisphere (0° westward to 180°) for following periods (corresponding to those in fig. 5): (A) Dec. 4–8, (B) Dec. 11–15, (C) Dec. 18–22, (D) Dec. 25–29, 1956. Note sharp increase in westerlies at mid-latitudes from A to B and decline from B to C.

bridged the United States mean trough in the North, leaving the most active portion in the Southwest.

These circulation changes encouraged further warming across the northern third of the United States (fig. 7c), except for New England where progressively weaker bursts of cold air still had a cooling effect. The Southeast remained much above normal for the third consecutive week, and the Southwest remained cool under the influence of northeasterly DN flow in the mean trough.

Precipitation was moderate to heavy in a broad band from central Texas to northern Florida, extending northeastward to southern Michigan and southern New England. Over-running moist Gulf air was also responsible for widespread fog over the eastern half of the United States, thus hampering air transportation during the pre-Christmas weekend.

DECEMBER 24–30

Extreme changes from the previous week over virtually the entire Northern Hemisphere can be seen by comparing the patterns of figure 5D and 5C. Rises at 700 mb. of 600 to 800 feet over Scandinavia contributed to almost complete breakdown of the Siberain blocking High, remnants of which were joined with the subtropical ridge off the east coast of Asia. Farther downstream, the Pacific mean trough remained strong and progressed to the central Pacific, while the eastern Pacific mean ridge built strongly and pushed into western North America. The mean trough in southwestern United States grew in amplitude and intensity as it progressed to eastern United States. It is surprising to note that these pronounced changes in longitudinal position and amplitude of wave train components from the central Pacific to the western Atlantic produced relatively minor changes in the wind speed profile (fig. 6D), and the zonal westerly index (fig. 2).

Oscillation of the United States 700-mb. mean pattern from that observed early in the month (fig. 5A) had, by the final week of December, produced a picture very similar to that of November's final week (fig. 6 of [6]). The oscillation was strongly reflected in the temperature pattern, especially in the Southeast where temperature anomalies decreased by 12 to 15° F. A well developed Great Basin High expanded the area influenced by radiational cooling, and warming (with respect to normal) occurred over the Great Plains.

Some modification of the precipitation picture accompanied the strong ridge buildup in the West and eastward progression of the mean trough. Both changes tended to dry out the country, the former by increasing stability and the latter by cutting off the Gulf moisture source.

4. SUMMARY

The general circulation of December 1956 was mainly comprised of two separate, interdependent, regional pat-

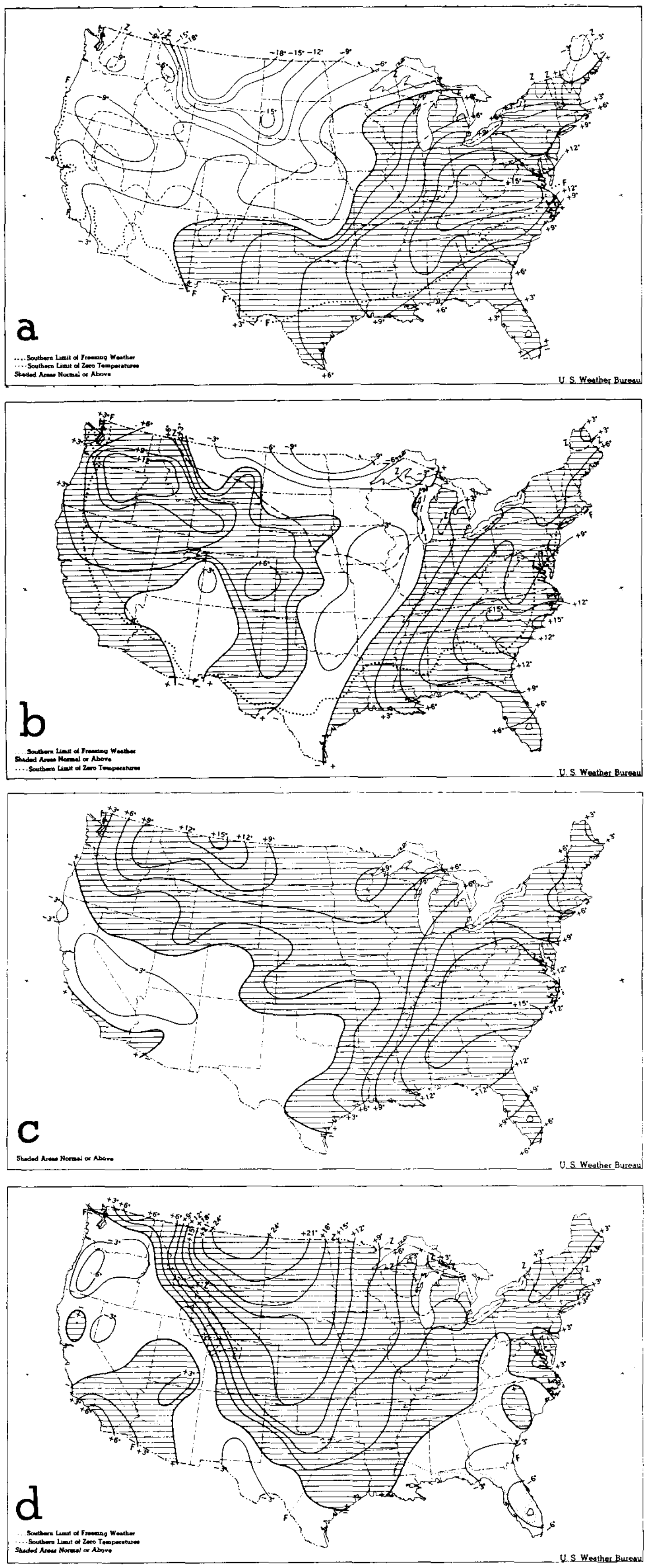

FIGURE 7.—Departure of average surface temperature from normal (° F.), centered on weekly periods corresponding to those of figure 4, (a) Dec. 3–9, (b) Dec. 6–10, (c) Dec. 17–23, and (d) Dec. 24–30. (From *Weekly Weather and Crop Bulletin, National Summary*, vol. XLIII, Nos. 50–53, Dec. 10, 17, 23, 31, 1956).

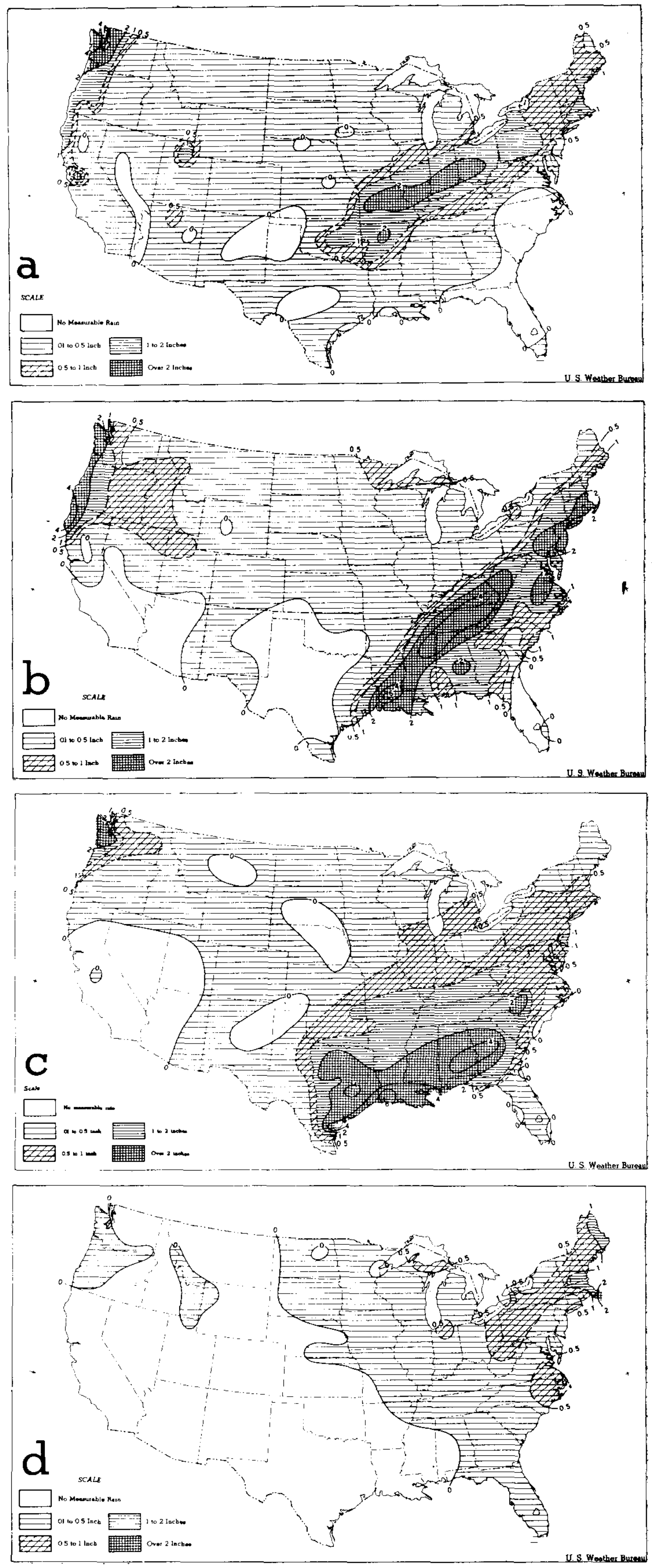

FIGURE 8.—Total precipitation (inches). (a) Dec. 3–9, (b) Dec. 6–10, (c) Dec. 17–23, and (d) Dec. 24–30, 1956. (From same source as figure 7.)

terns. Low-index and blocking characterized the Eastern Hemisphere circulation, while in the Western Hemisphere the 5-day mean zonal index reached its highest December value in 14 years of record.

United States temperature anomalies reflected the high-index character of the Western Hemisphere circulation by warming at least one class from the previous month at 79 of 100 representative stations to break records for the month in 8 States and daily records in 27 States.

Intramonthly variability was a conspicuous circulation feature, as evidenced by fluctuations of the zonal index and a complete oscillation of the mean trough-ridge structure over the United States.

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Water Supply Forecast for the Western United States

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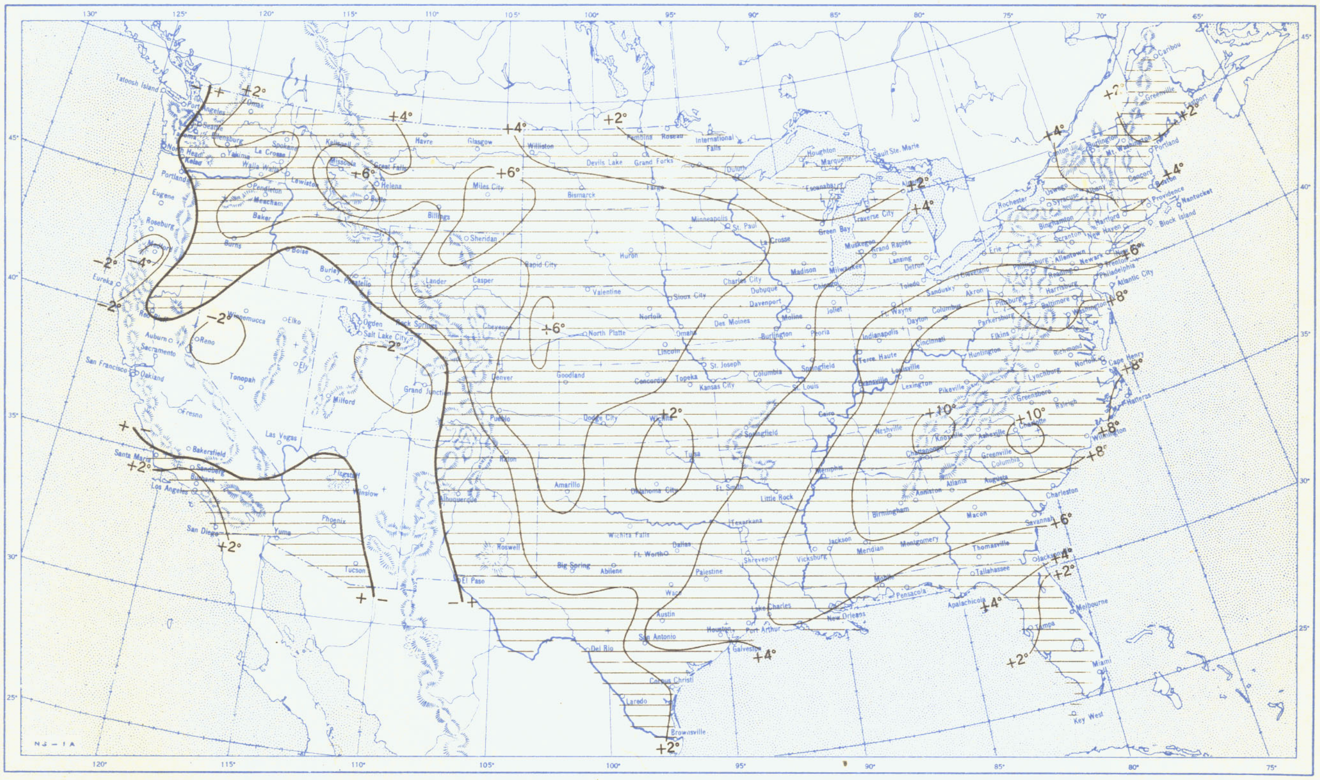
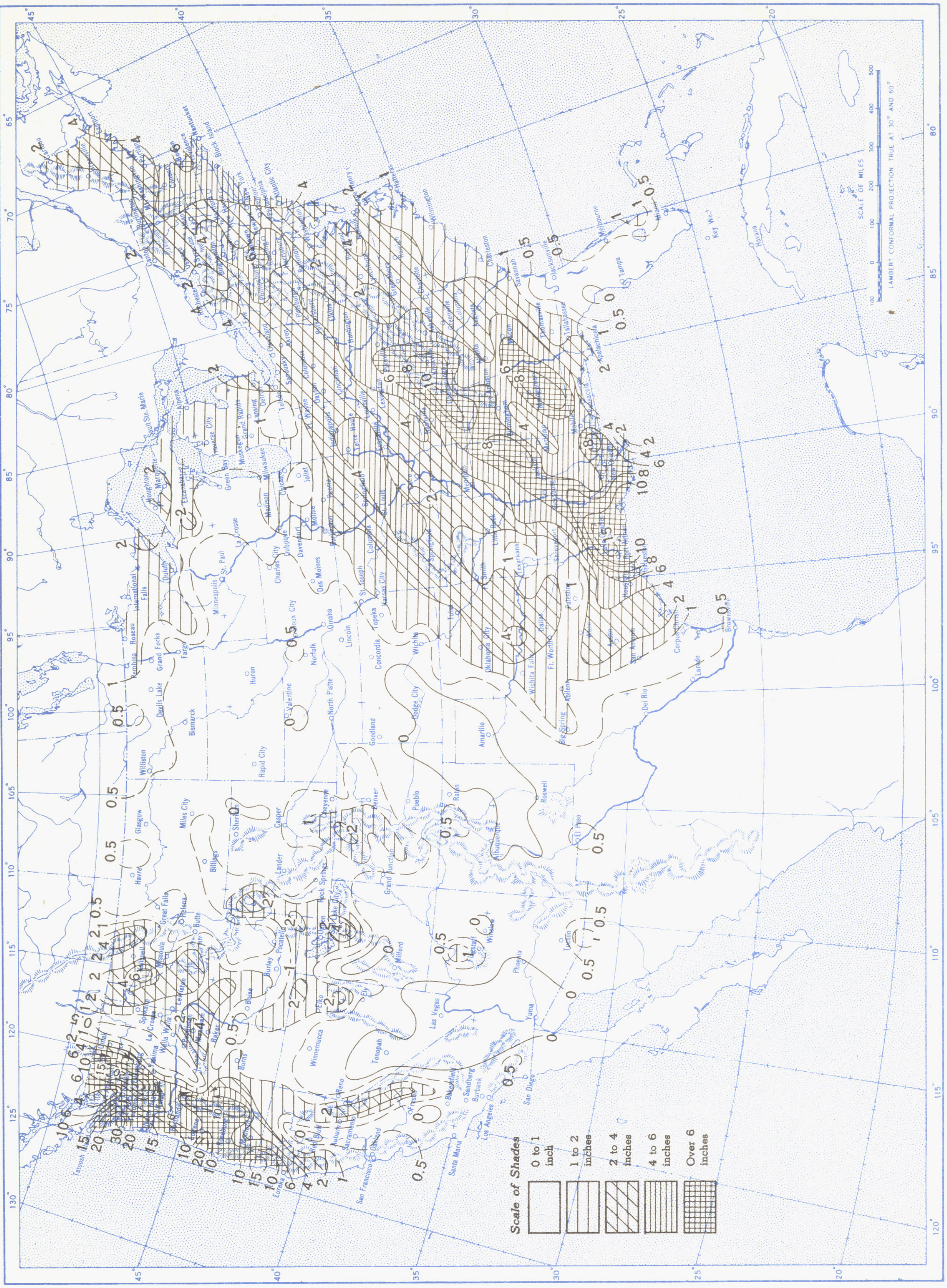
Chart I. A. Average Temperature (°F.) at Surface, December 1956.

B. Departure of Average Temperature from Normal (°F.), December 1956.



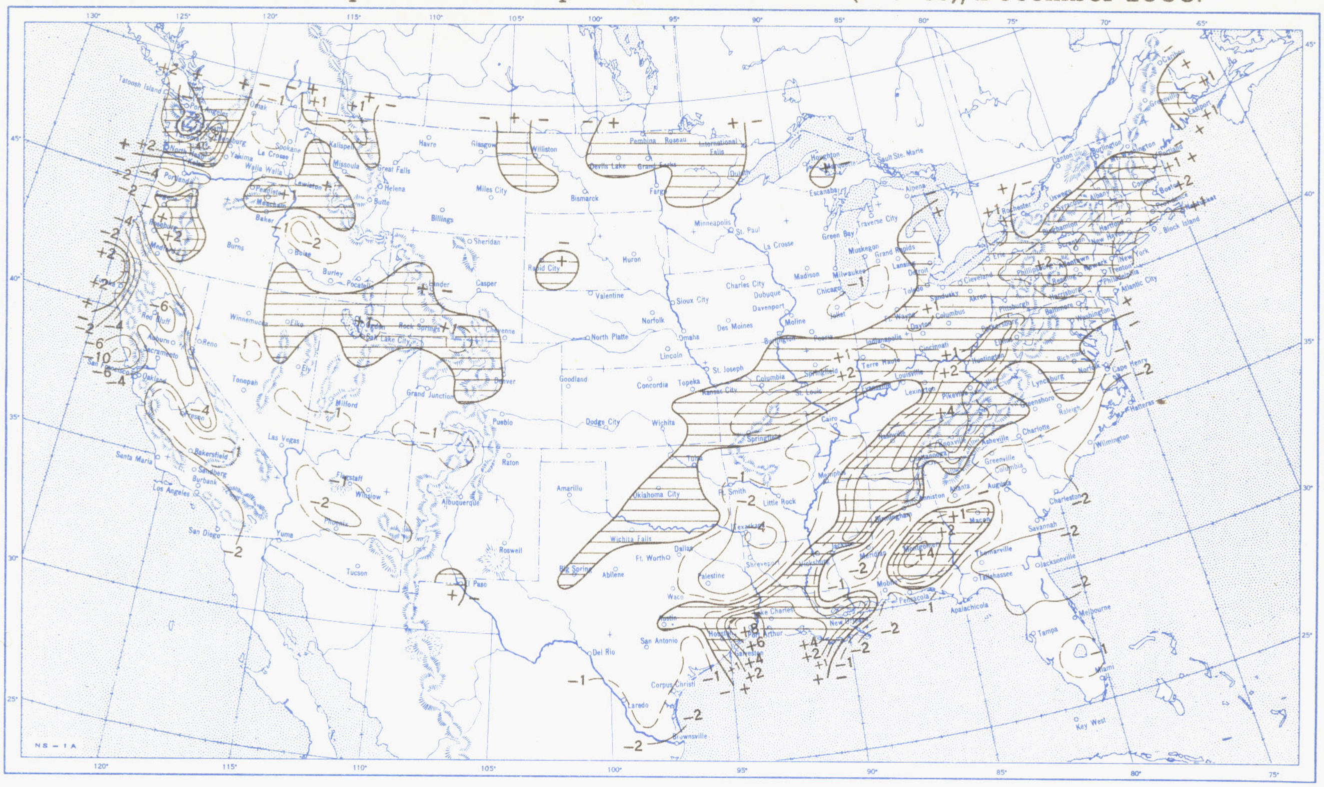
A. Based on reports from 800 Weather Bureau and cooperative stations. The monthly average is half the sum of the monthly average maximum and monthly average minimum, which are the average of the daily maxima and daily minima, respectively.
B. Normal average monthly temperatures are computed for Weather Bureau stations having at least 10 years of record.

Chart II. Total Precipitation (Inches), December 1956.

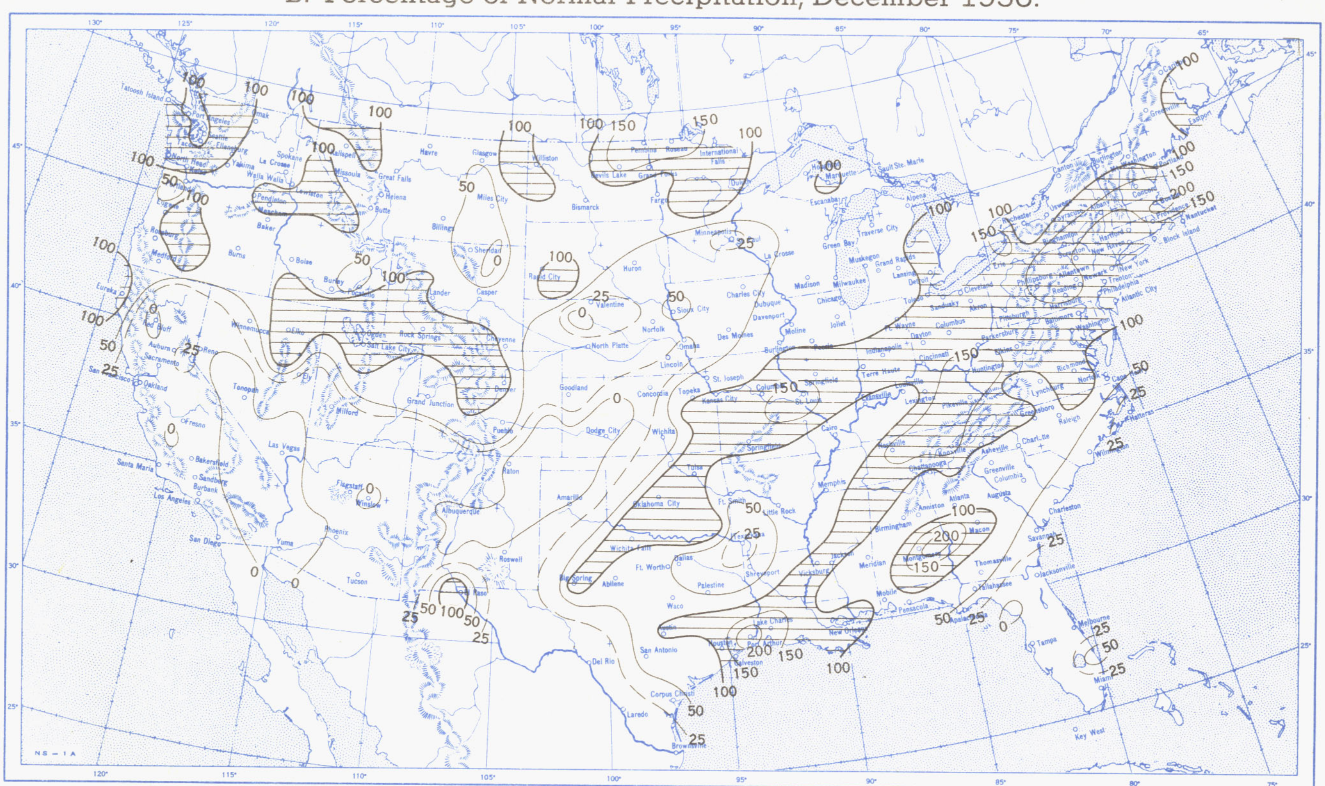


Based on daily precipitation records at 800 Weather Bureau and cooperative stations.

Chart III. A. Departure of Precipitation from Normal (Inches), December 1956.

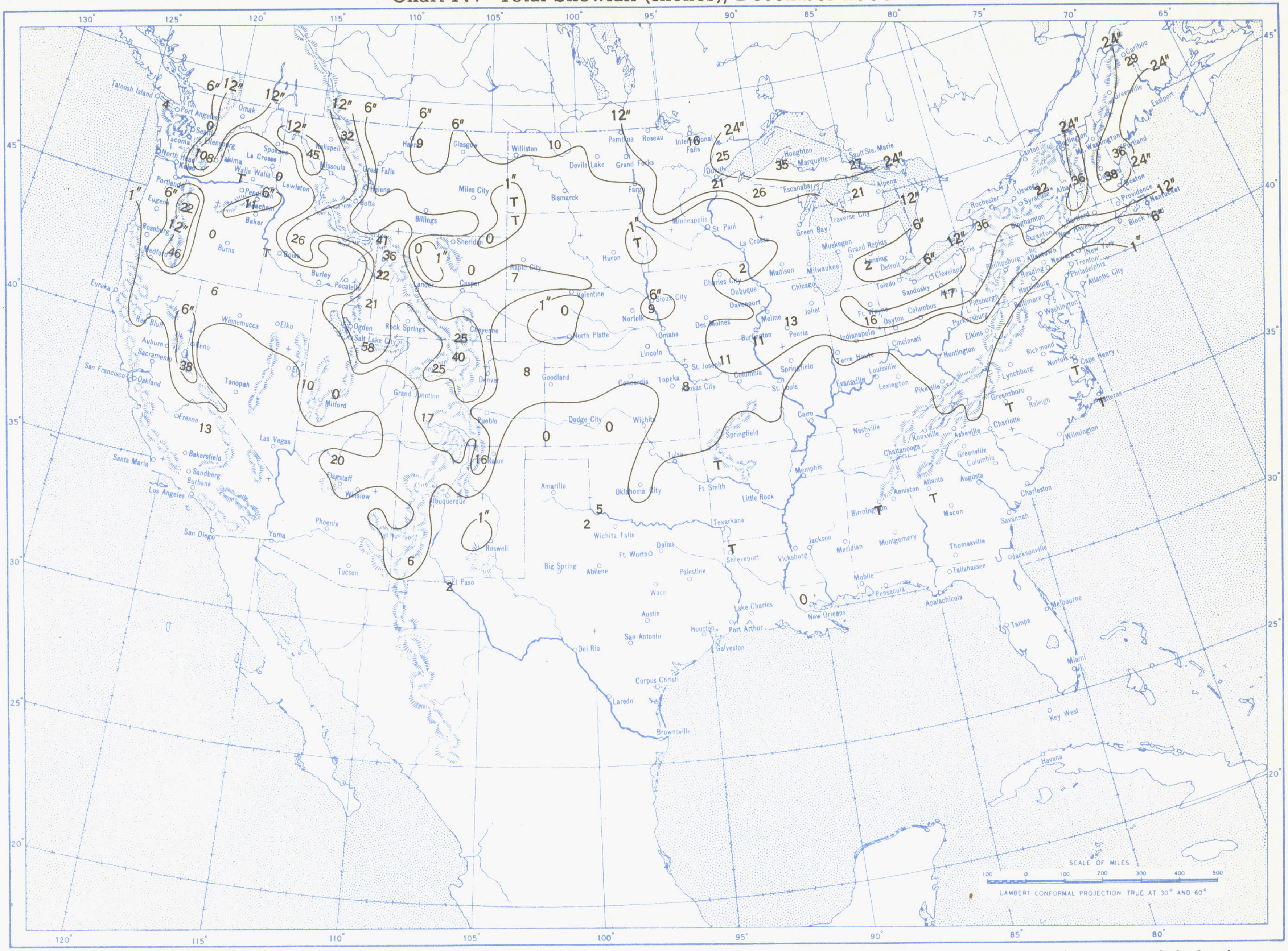


B. Percentage of Normal Precipitation, December 1956.



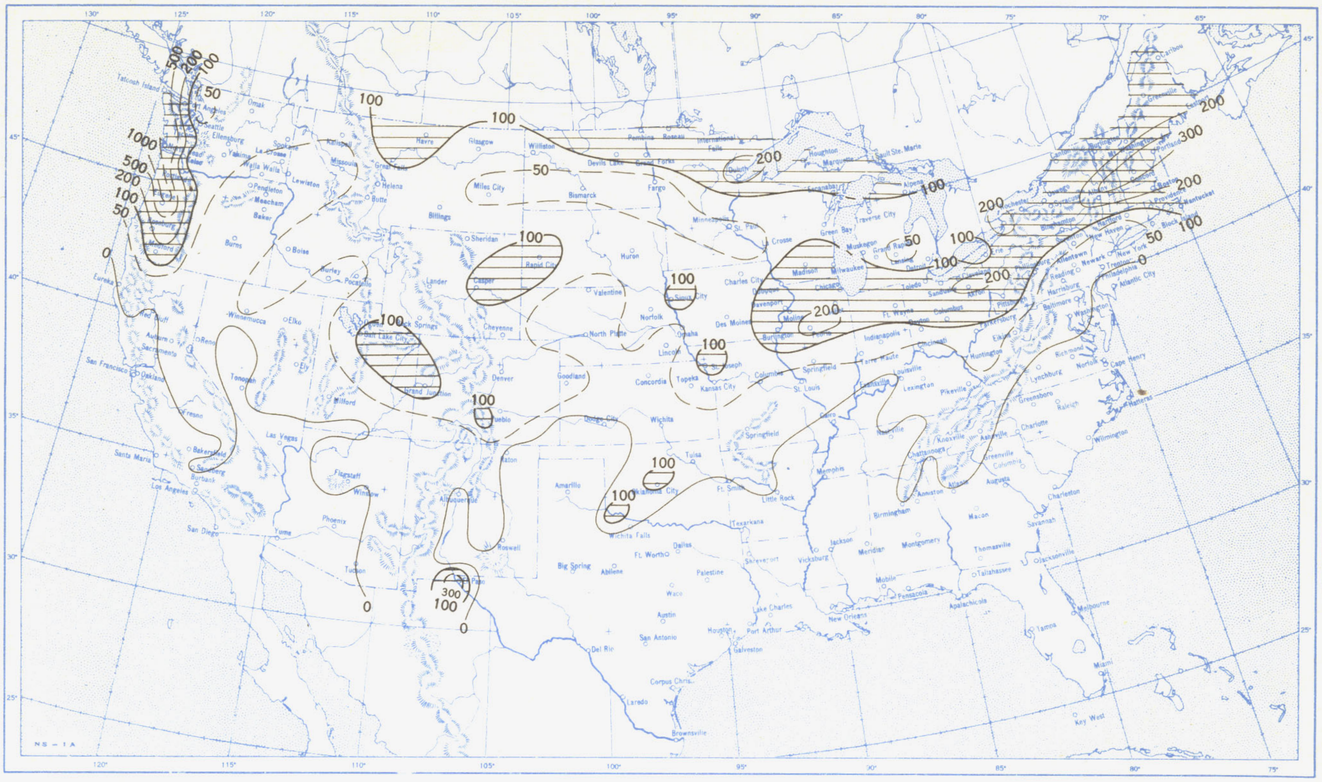
Normal monthly precipitation amounts are computed for stations having at least 10 years of record.

Chart IV. Total Snowfall (Inches), December 1956.

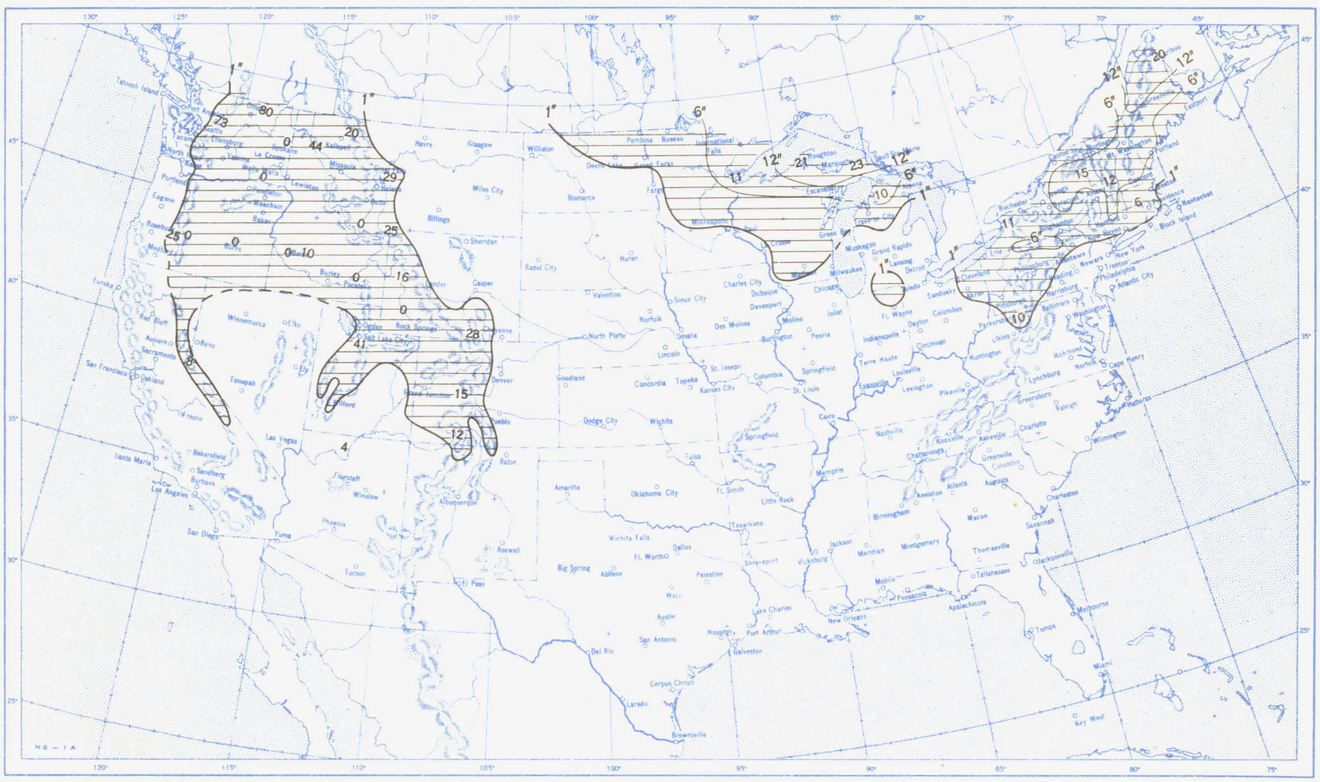


This is the total of unmelted snowfall recorded during the month at Weather Bureau and cooperative stations. This chart and Chart V are published only for the months of November through April although of course there is some snow at higher elevations, particularly in the far West, earlier and later in the year.

Chart V. A. Percentage of Normal Snowfall, December 1956.

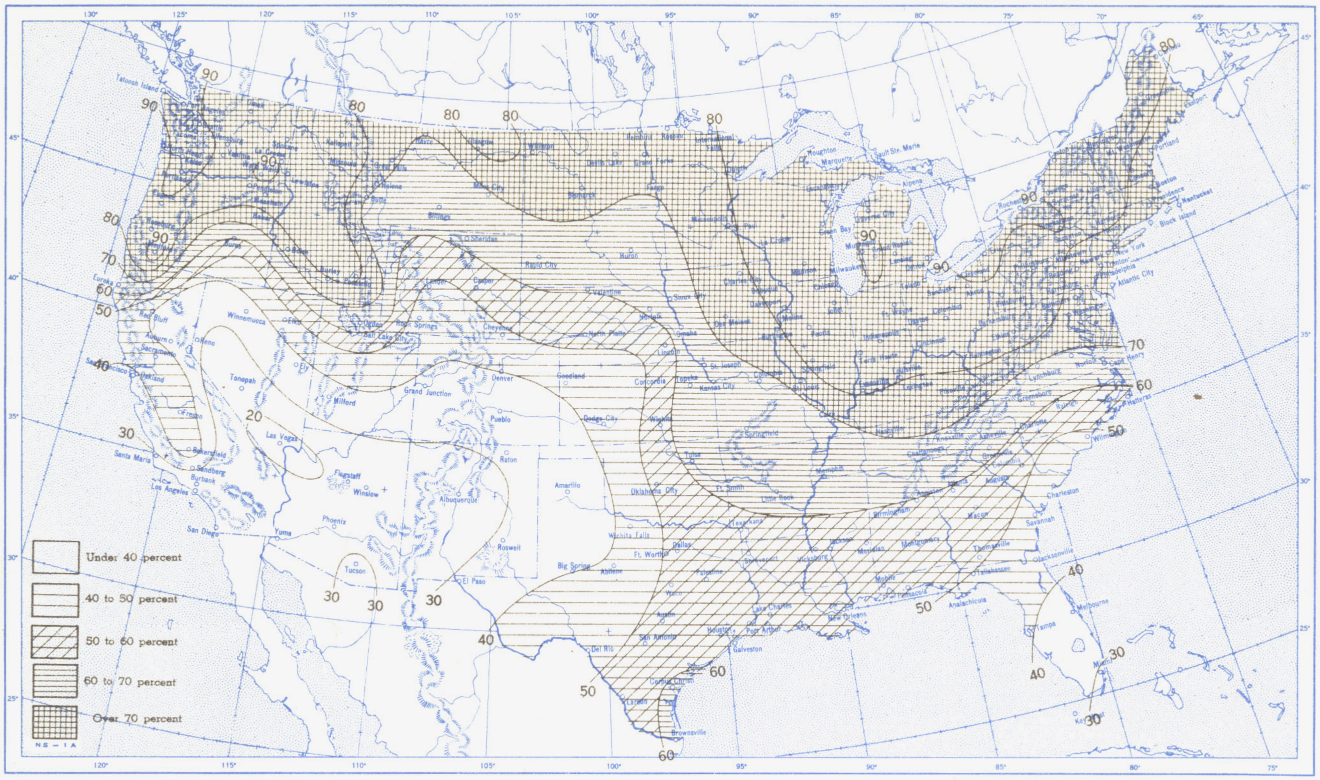


B. Depth of Snow on Ground (Inches). 7:30 a. m. E. S. T., December 31, 1956.

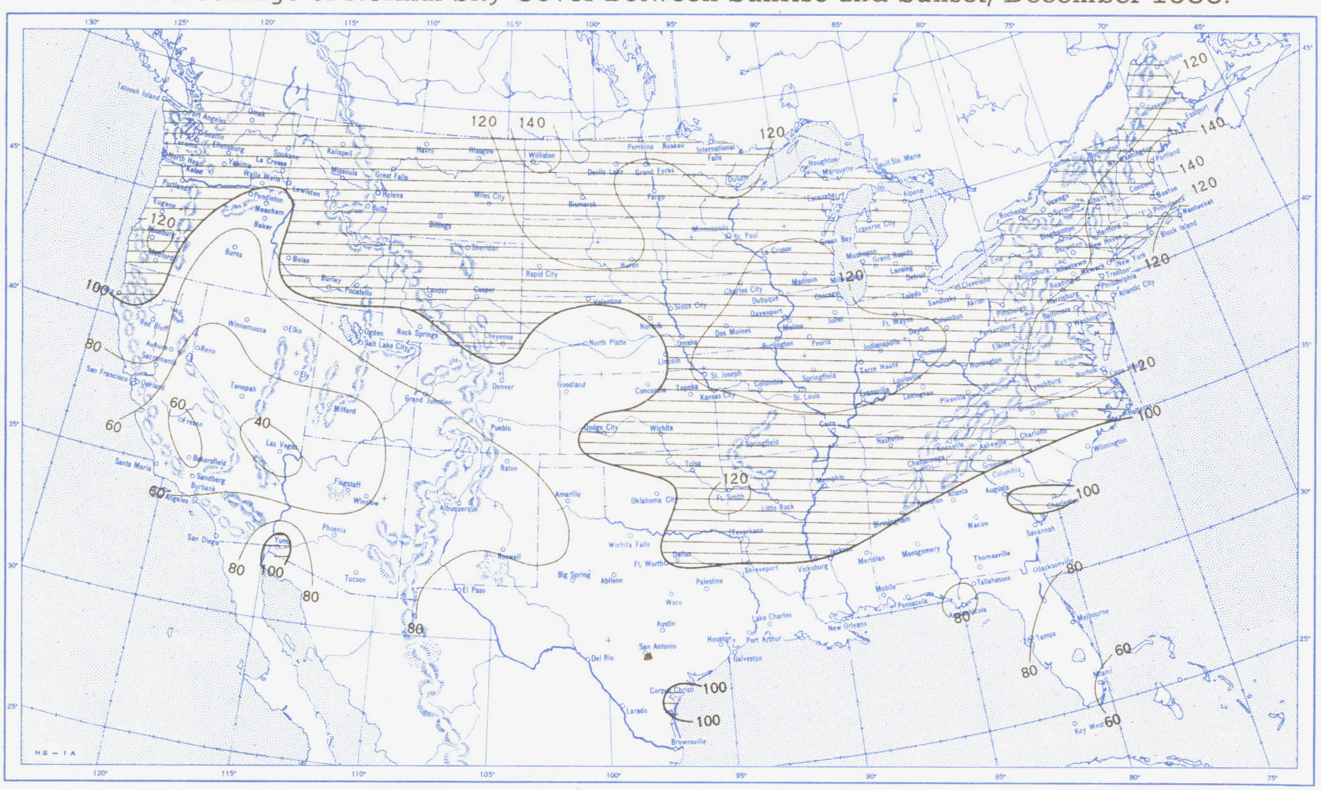


A. Amount of normal monthly snowfall is computed for Weather Bureau stations having at least 10 years of record.
B. Shows depth currently on ground at 7:30 a. m. E.S.T., of the Tuesday nearest the end of the month. It is based on reports from Weather Bureau and cooperative stations. Dashed line shows greatest southern extent of snowcover during month.

Chart VI. A. Percentage of Sky Cover Between Sunrise and Sunset, December 1956.

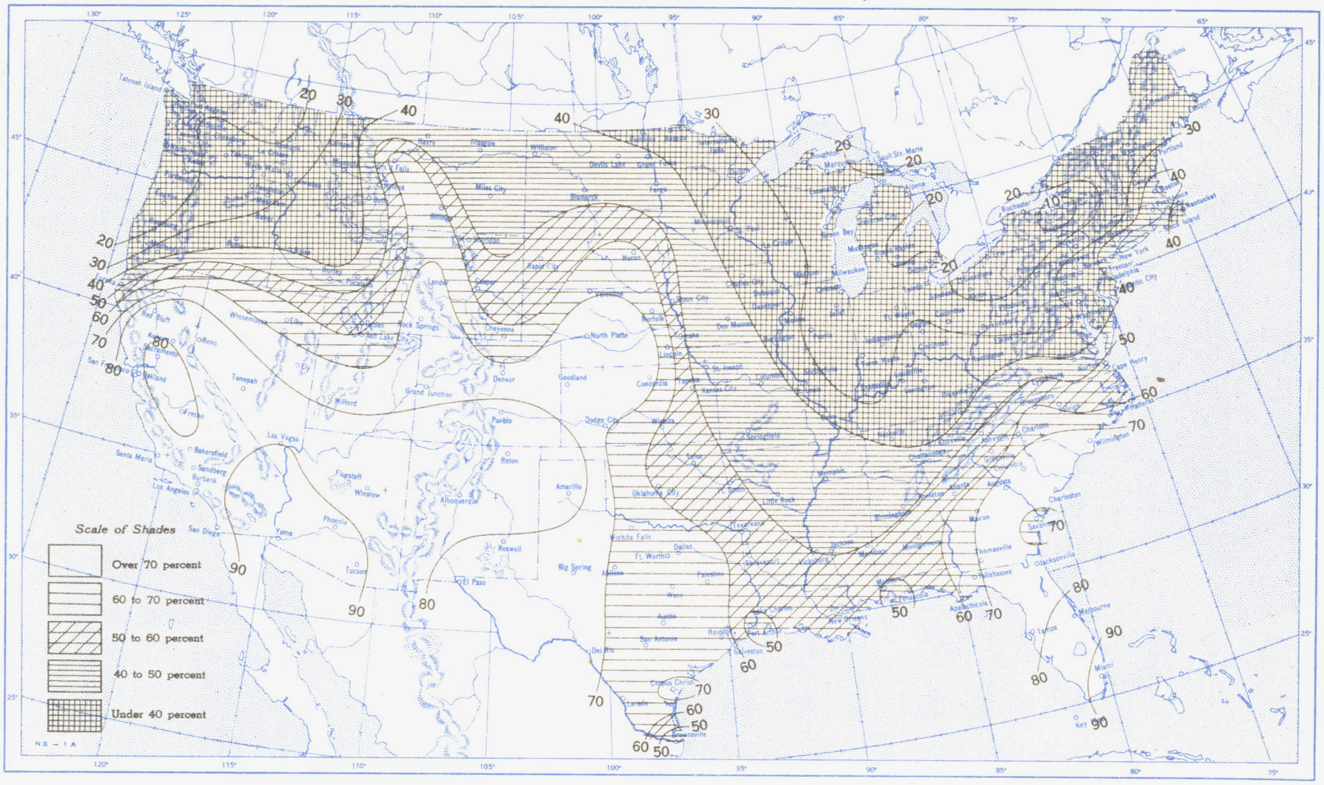


B. Percentage of Normal Sky Cover Between Sunrise and Sunset, December 1956.

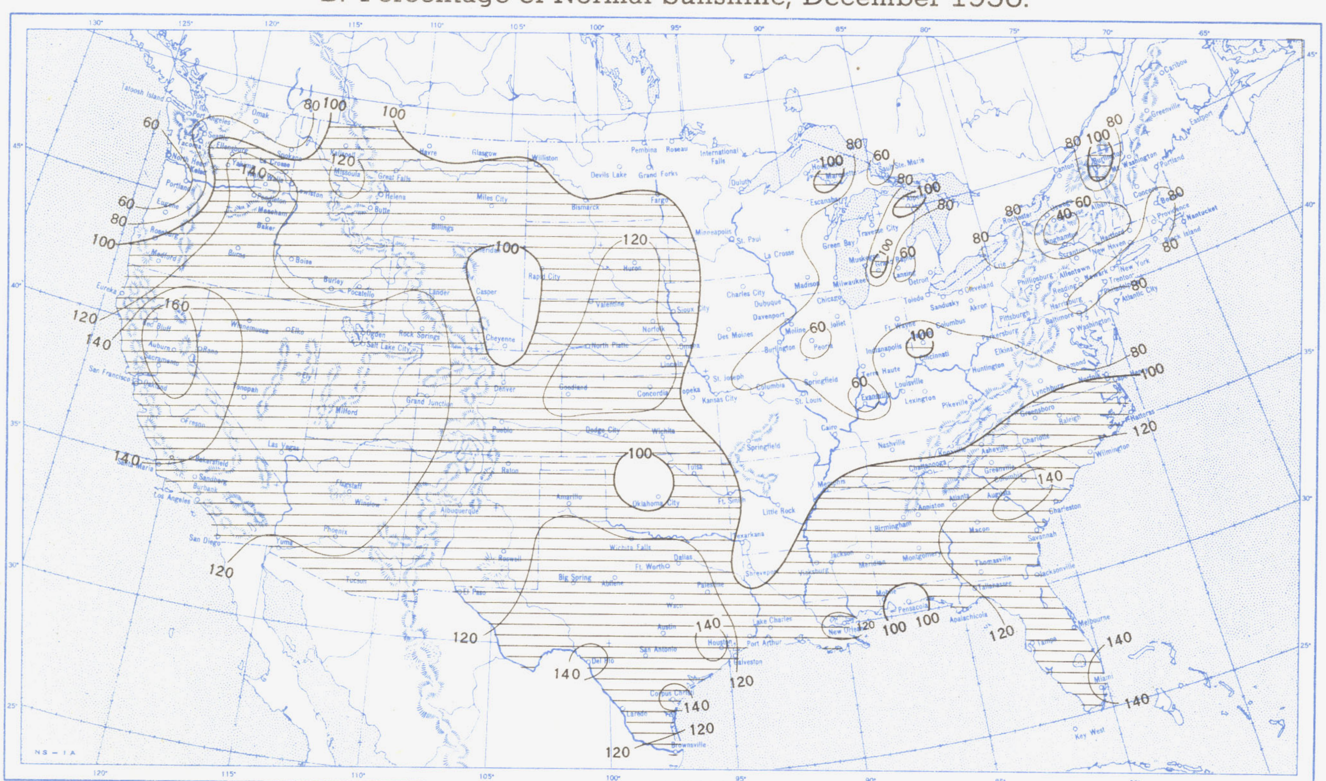


A. In addition to cloudiness, sky cover includes obscuration of the sky by fog, smoke, snow, etc. Chart based on visual observations made hourly at Weather Bureau stations and averaged over the month. B. Computations of normal amount of sky cover are made for stations having at least 10 years of record.

Chart VII. A. Percentage of Possible Sunshine, December 1956.



B. Percentage of Normal Sunshine, December 1956.



A. Computed from total number of hours of observed sunshine in relation to total number of possible hours of sunshine during month. B. Normals are computed for stations having at least 10 years of record.

Chart VIII. Average Daily Values of Solar Radiation, Direct + Diffuse, December 1956. Inset: Percentage of Mean Daily Solar Radiation, December 1956. (Mean based on period 1951-55.)

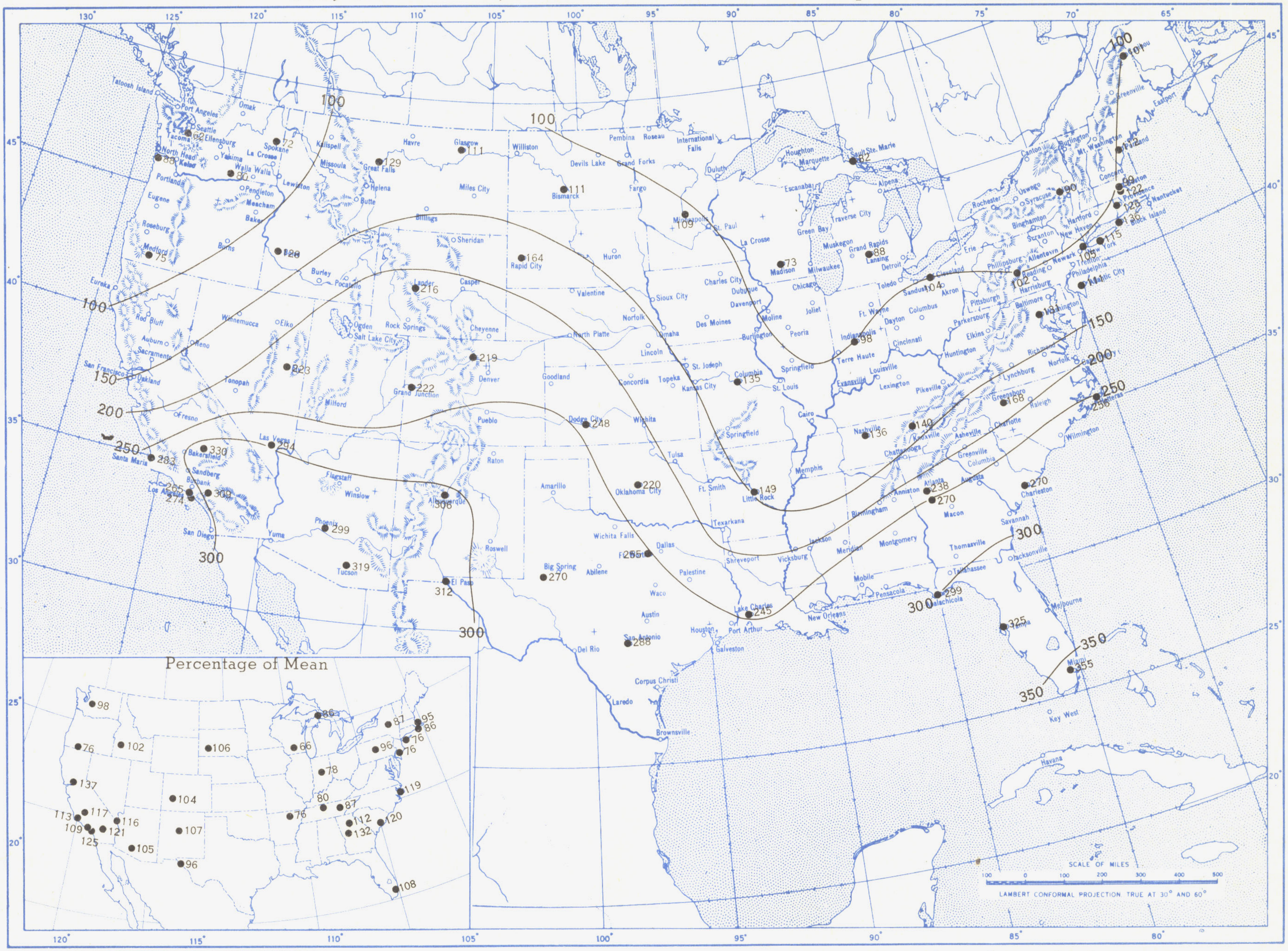
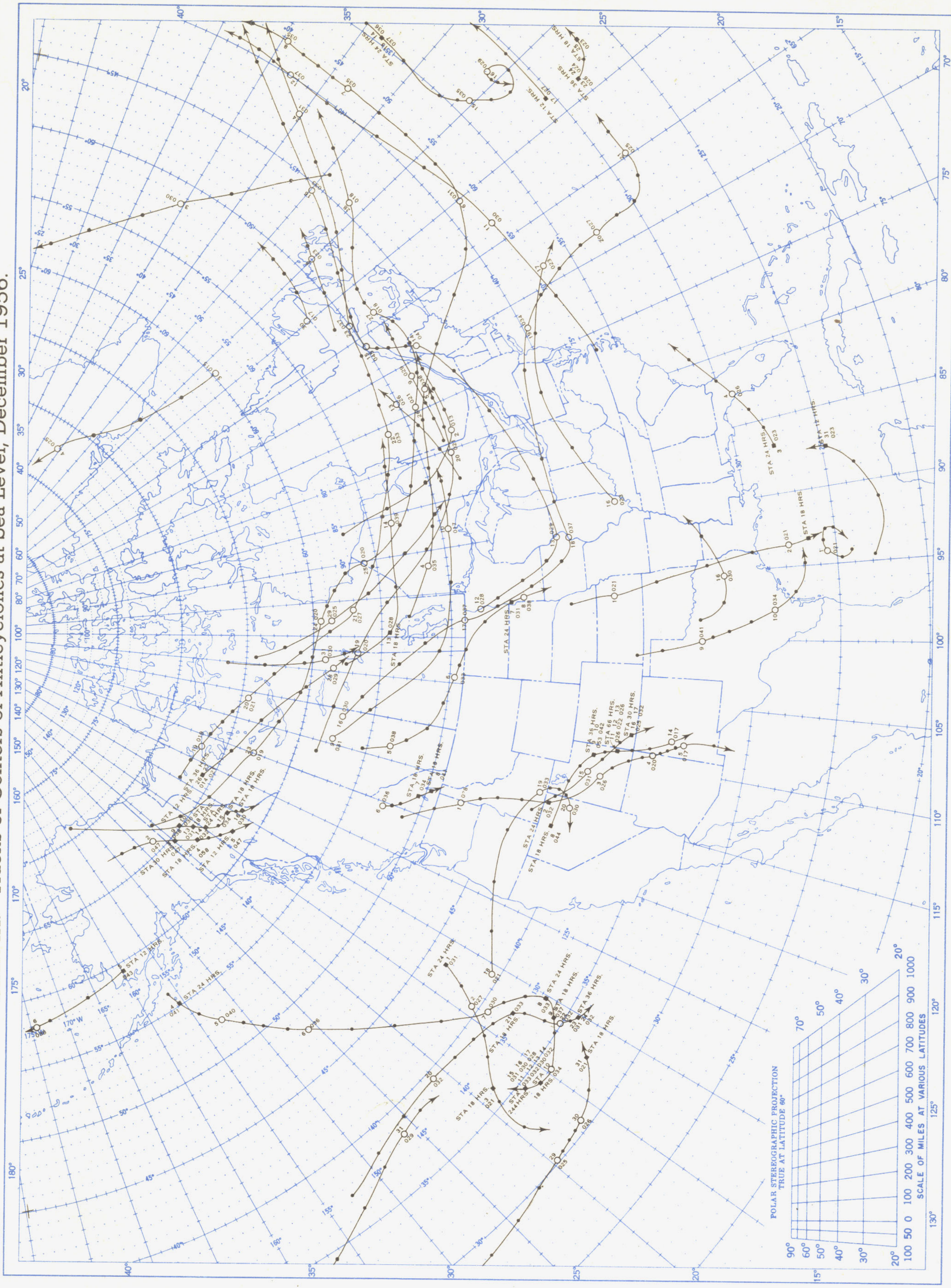


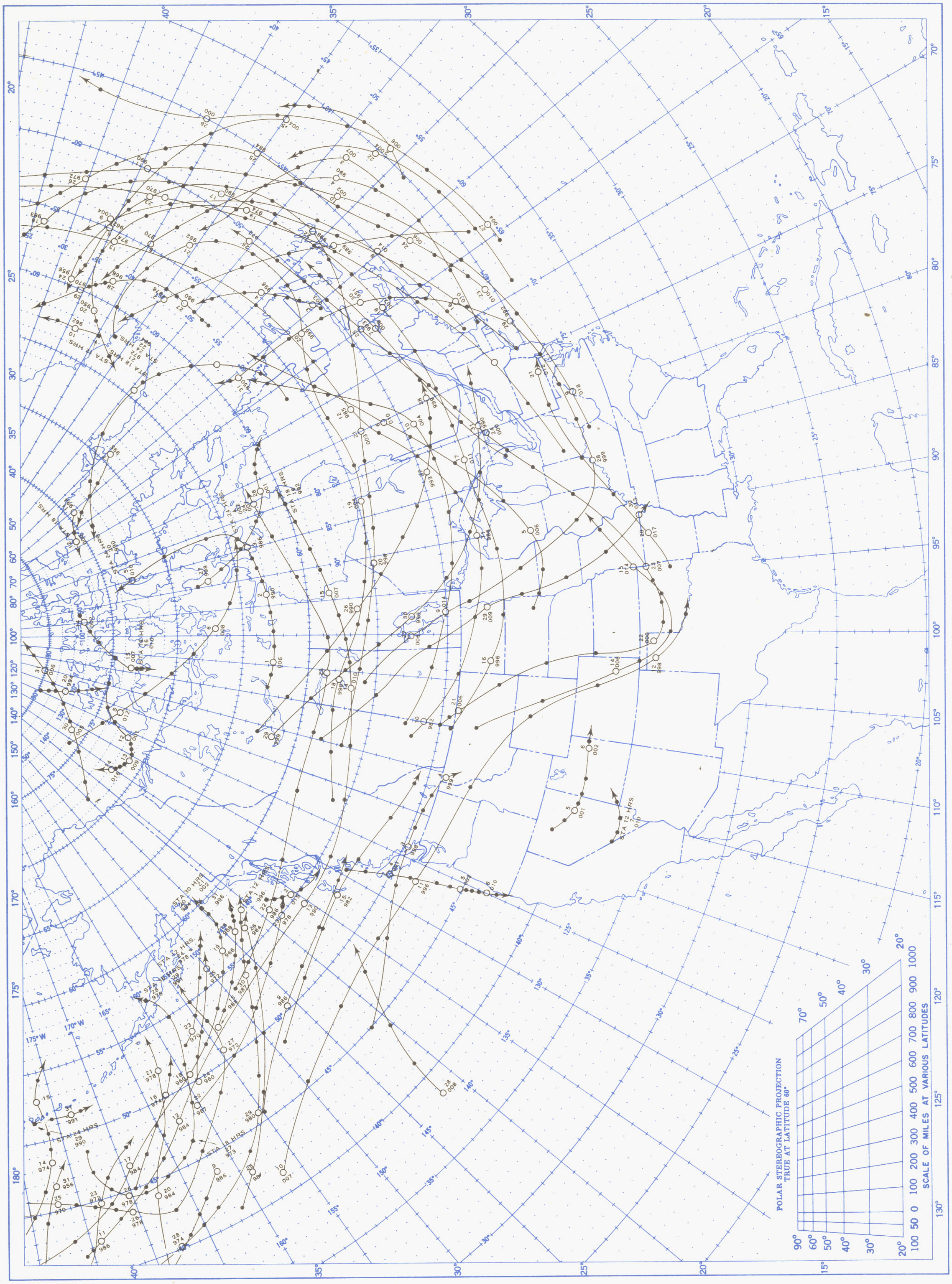
Chart shows mean daily solar radiation, direct + diffuse, received on a horizontal surface in langleys (1 langley = 1 gm. cal. cm.$^{-2}$). Basic data for isolines are shown on chart. Further estimates are obtained from supplementary data for which limits of accuracy are wider than for those data shown.

Chart IX. Tracks of Centers of Anticyclones at Sea Level, December 1956.



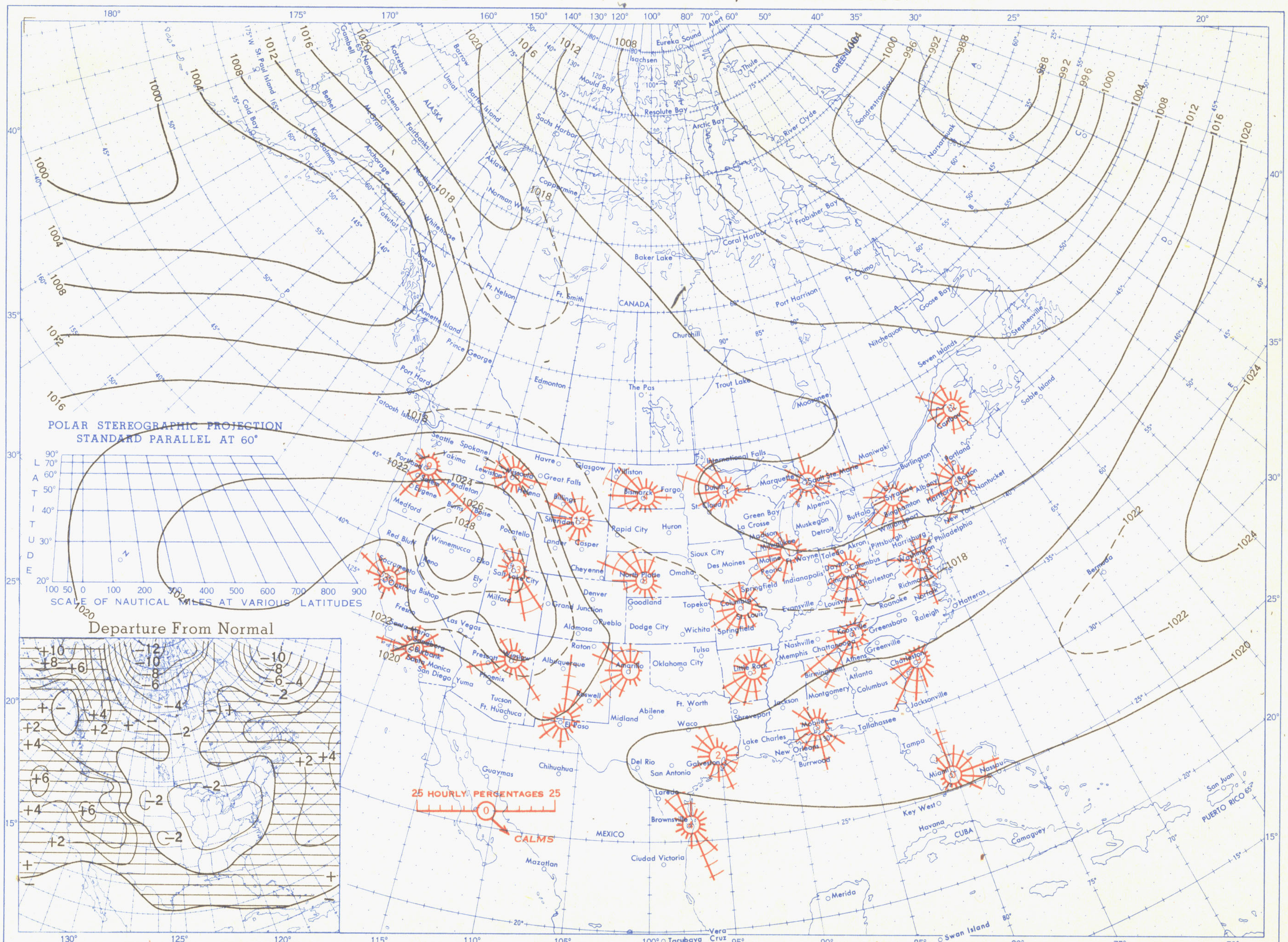
Circle indicates position of center at 7:30 a. m. E. S. T. Figure above circle indicates date, figure below, pressure to nearest millibar. Dots indicate intervening 6-hourly positions. Squares indicate position of stationary center for period shown. Dashed line in track indicates reformation at new position. Only those centers which could be identified for 24 hours or more are included.

Chart X. Tracks of Centers of Cyclones at Sea Level, December 1956.



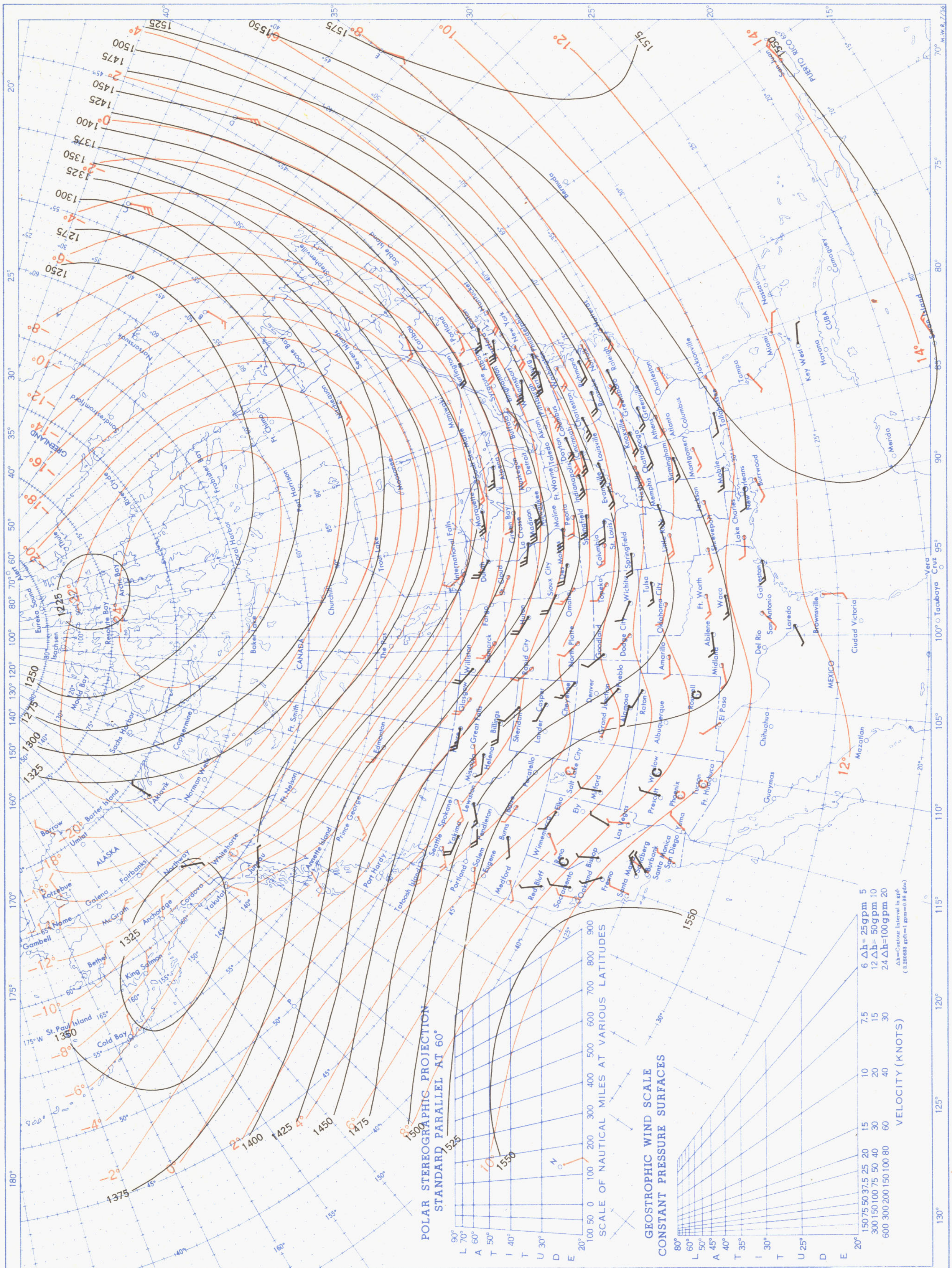
Circle indicates position of center at 7:30 a. m. E. S. T. See Chart IX for explanation of symbols.

Chart XI. Average Sea Level Pressure (mb.) and Surface Windroses, December 1956. Inset: Departure of Average Pressure (mb.) from Normal, December 1956.



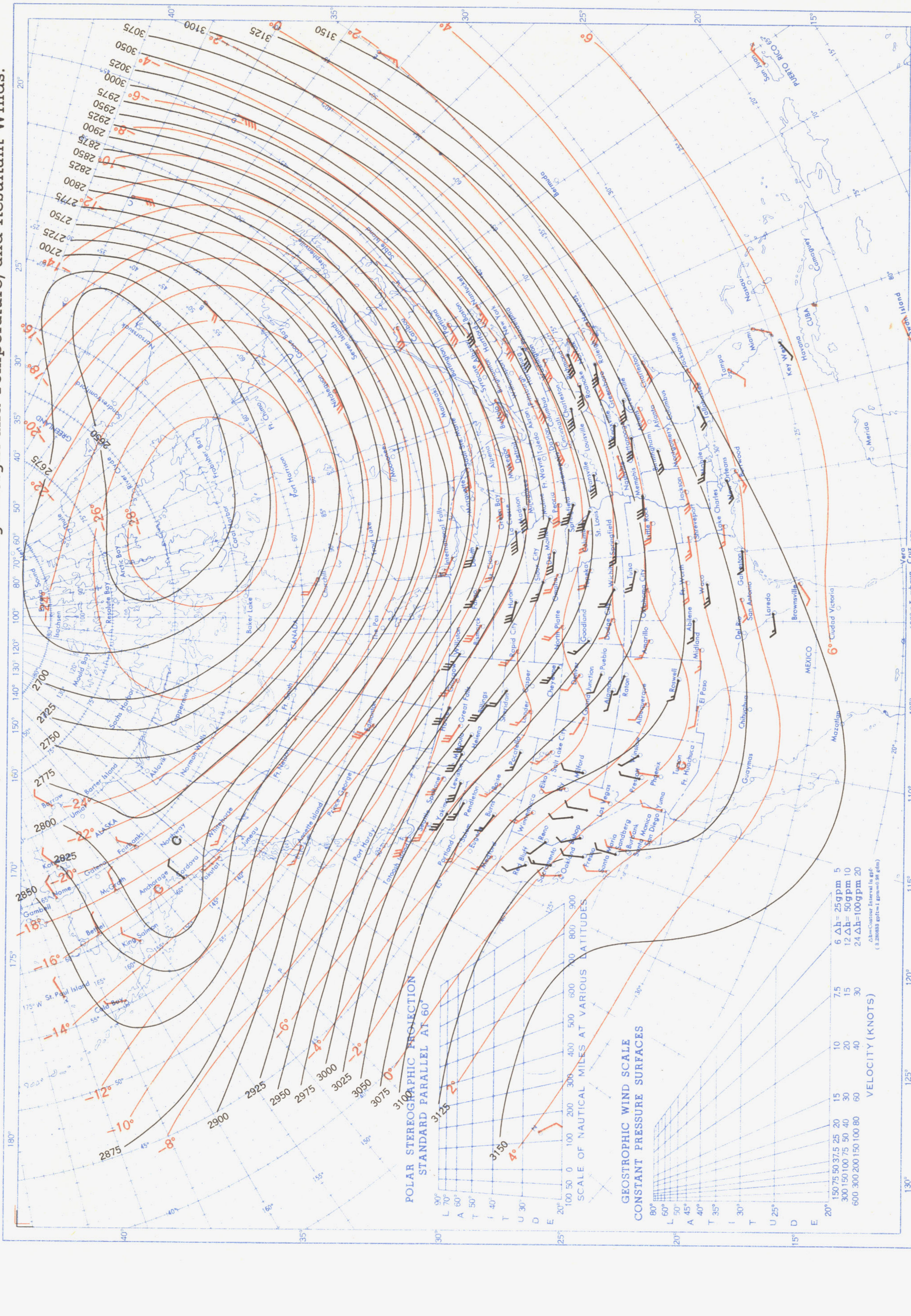
Average sea level pressures are obtained from the averages of the 7:30 a. m. and 7:30 p. m. E. S. T. readings. Windroses show percentage of time wind blew from 16 compass points or was calm during the month. Pressure normals are computed for stations having at least 10 years of record and for 10° intersections in a diamond grid based on readings from the Historical Weather Maps (1899-1939) for the 20 years of most complete data coverage prior to 1940.

Chart XII. 850-mb. Surface, 0300 GMT, December 1956. Average Height and Temperature, and Resultant Winds.



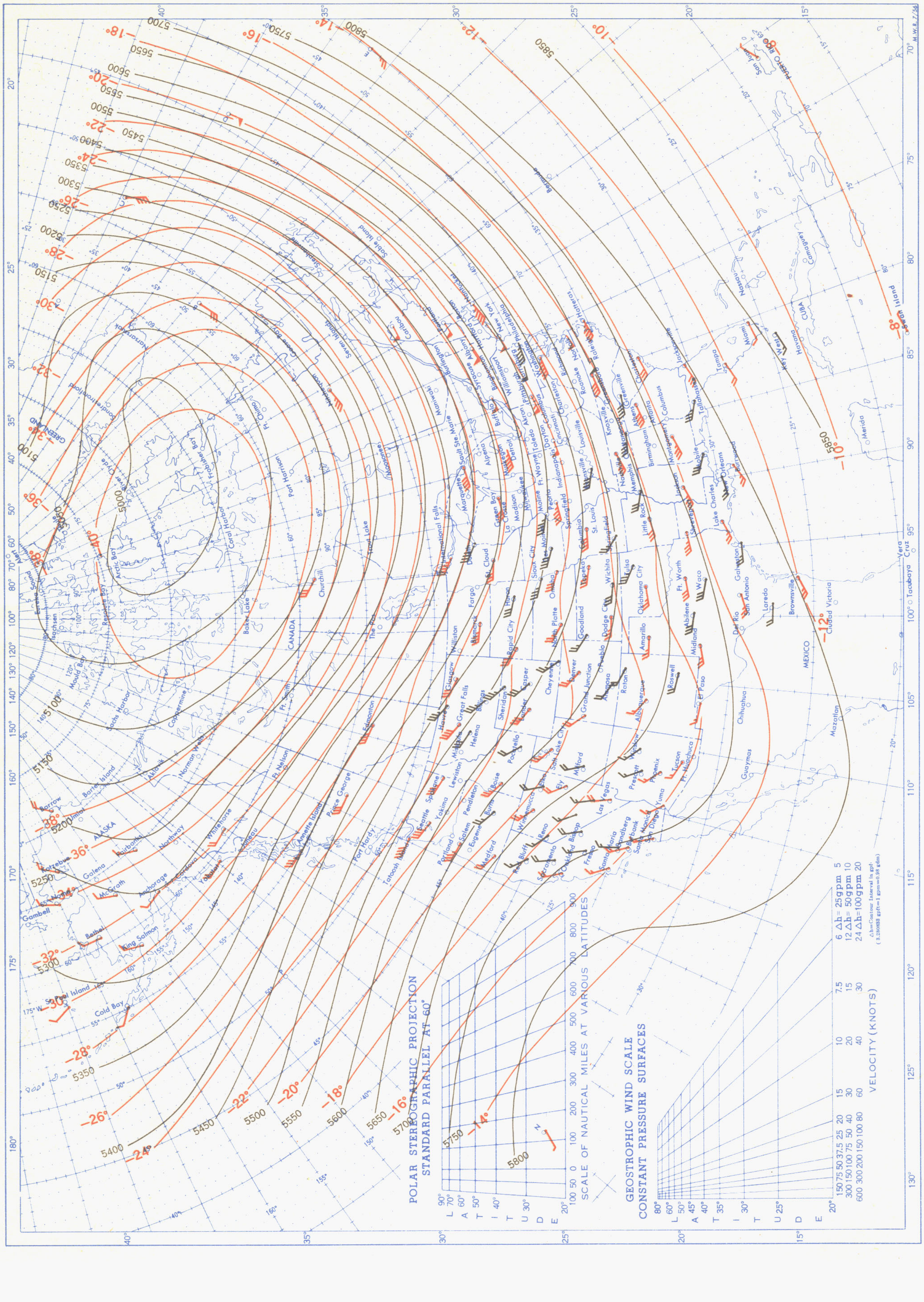
Height in geopotential meters (1 g.p.m. = 0.98 dynamic meters). Temperature in °C. Wind speed in knots; flag represents 50 knots, full feather 10 knots, and half feather 5 knots. Winds shown in red are based on rawins taken at the indicated pressure surface and time. Those in black are based on pibals taken at 2100 GMT and are for the nearest standard height level.

Chart XIII. 700-mb. Surface, 0300 GMT, December 1956. Average Height and Temperature, and Resultant Winds.



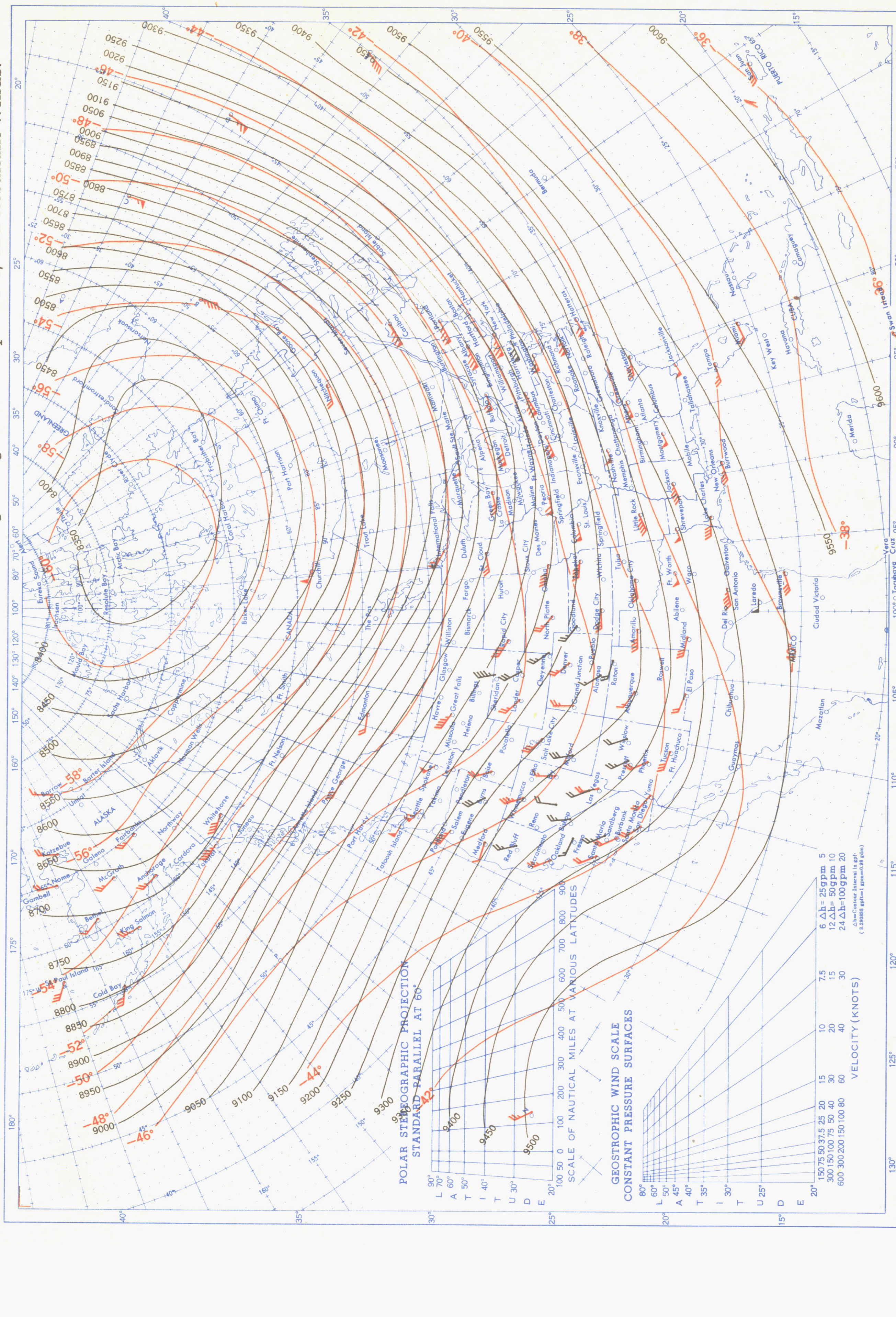
See Chart XII for explanation of map.

Chart XIV. 500-mb. Surface, 0300 GMT, December 1956. Average Height and Temperature, and Resultant Winds.



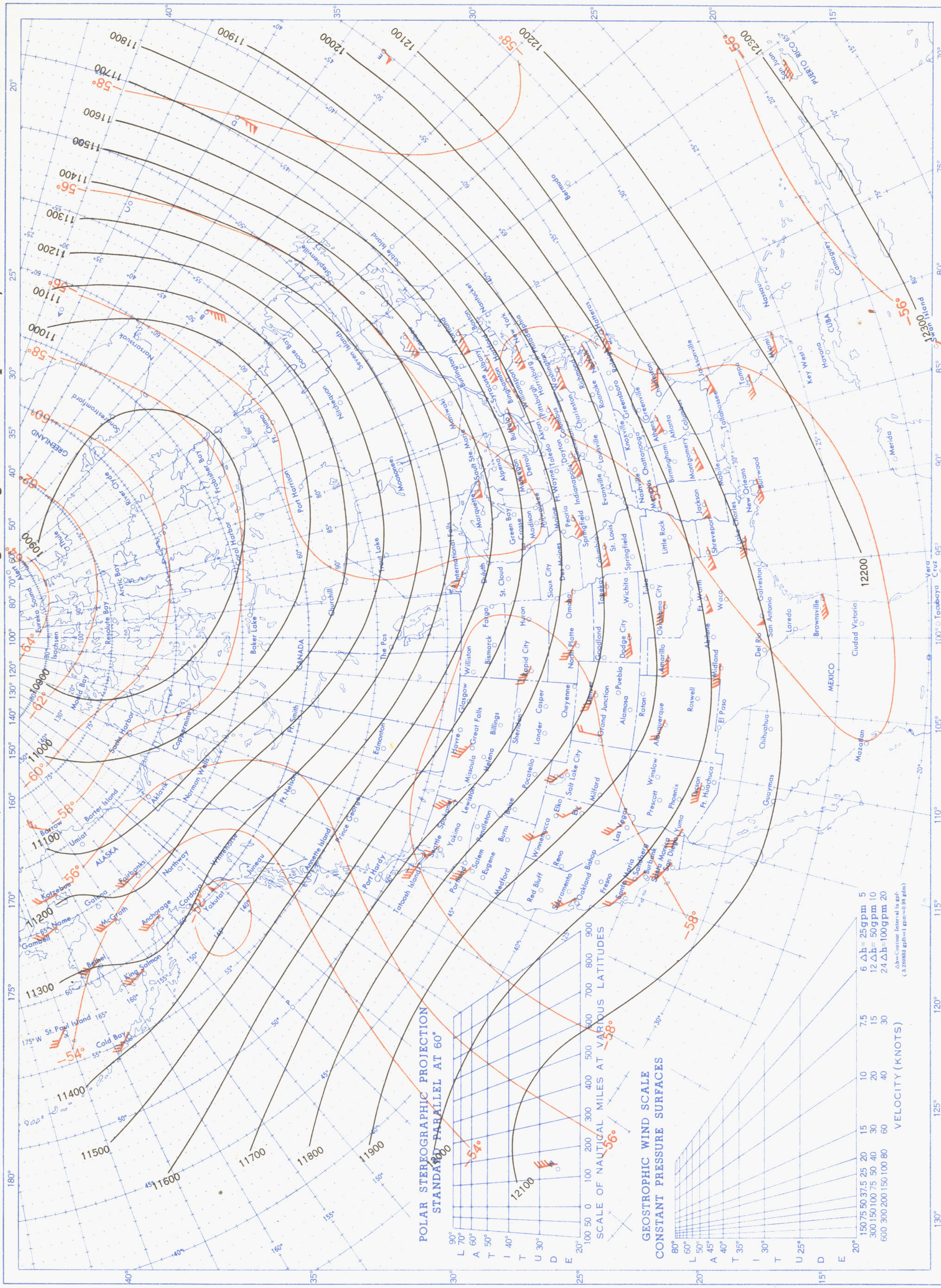
See Chart XII for explanation of map.

Chart XV. 300-mb. Surface, 0300 GMT, December 1956. Average Height and Temperature, and Resultant Winds.



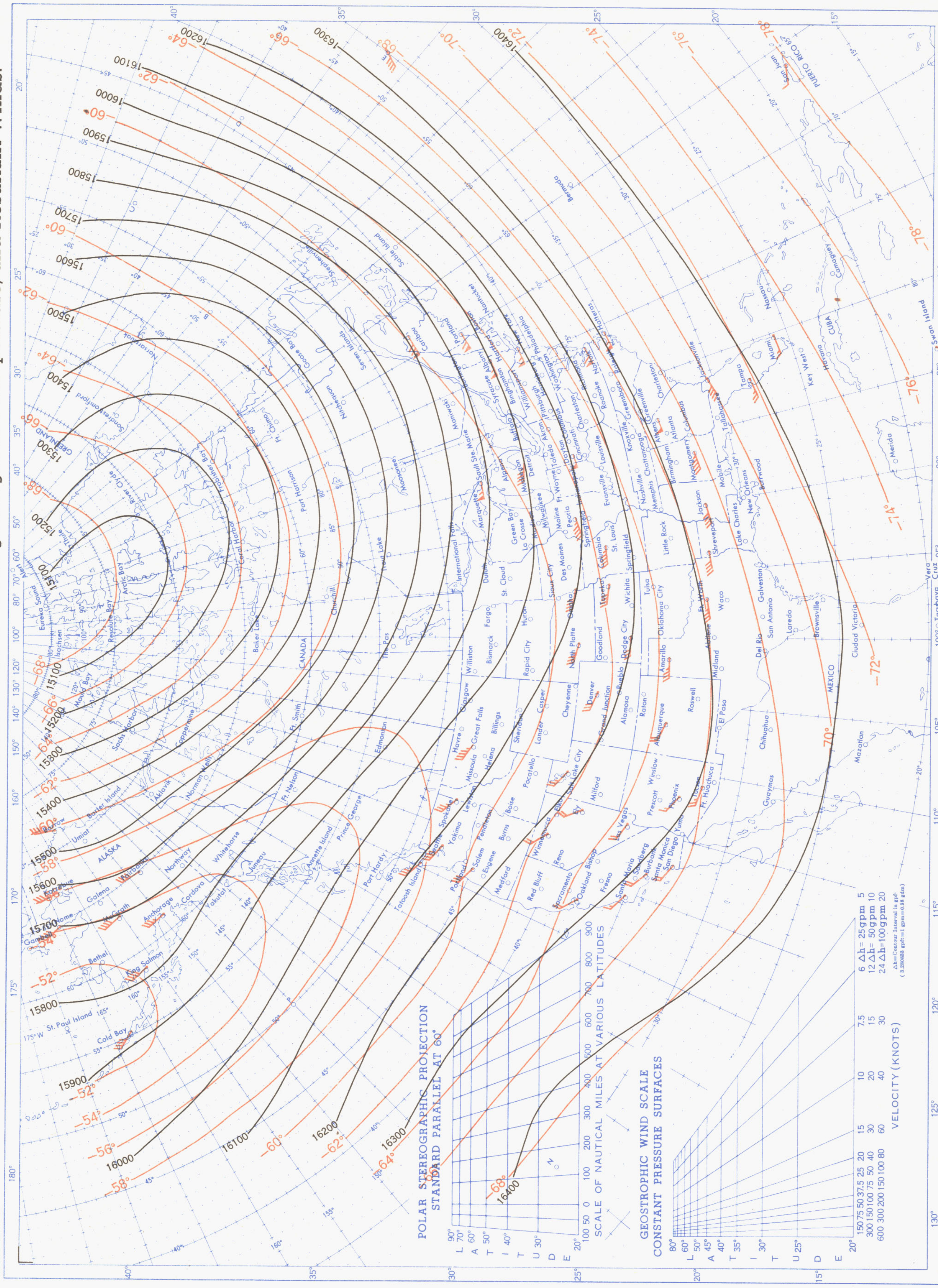
See Chart XII for explanation of map.

Chart XVI. 200-mb. Surface, 0300 GMT, December 1956. Average Height and Temperature, and Resultant Winds.



See Chart XII for explanation of map. All winds are from rawin reports.

Chart XVII. 100-mb. Surface, 0300 GMT, December 1956. Average Height and Temperature, and Resultant Winds.



See Chart XII for explanation of map. All winds are from rawin reports.